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REPORT ON THE CHEMICAL COMPOSITION OF NATURAL GAS.

Made by PROF. FRANCIS C. PHILLIPS, of the Western University, Allegheny, for the Geological Survey of Pennsylvania.

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COLLECTION OF SAMPLES.

Glass vessels, having a capacity of 250 to 400 cubic centimetres, were carefully dried by a current of warm air, and in order to obtain the gas as nearly as possible free from moisture, the following method was employed.

Glacial phosphoric acid, partially cooled from fusion, was drawn out into fine threads. A considerable number of such threads, in short pieces, could be pushed through the glass stop-cocks, by

which the vessels were closed, and left in the vessels, which were then ready for the reception of gas samples. It is of importance to state that these vessels had been long in use for the same purpose, and had been proved to be air-tight by thorough and repeated tests. In collecting the samples, several of these glass cylinders were connected in a series with the well or main by a short rubber hose, and gas allowed to flow for twenty minutes through them all. The stop-cocks were then closed in such a manner as to leave a slight excess of gas pressure in each vessel.

The stop-cocks (which had previously been well-greased with a mixture of tallow and wax), were then wound over and completely covered by fine cord, so that each resembled a ball of cord. The capillary ends of the cylinders were then closed by short pieces of thick rubber hose plugged with glass rods. By this mode of wrapping all movement of the stop-cocks during transportation on railroads is prevented. The gas thus left in contact with the glacial phosphoric acid was gradually dried and ready for analysis on reaching the laboratory.

The common method of taking a gas sample in a glass cylinder having finely drawn out ends, which are to be sealed by a flame when the vessel is filled, is not applicable in the case of natural gas. The constant escape of gas about a gas well renders the use of a flame absolutely impossible on account of the danger of accident. Vessels closed by glass stop-cocks capable of holding a gas sample for many weeks without risk of leaking are now supplied by dealers.

METHOD OF ANALYSIS.

The determination of carbon and hydrogen existing in combustible form in the gas was conducted by combustion over oxide of copper in a porcelain tube, which was kept at a bright-red heat, and the resulting carbon dioxide and water, collected separately and weighed.

One of the glass cylinders, filled with gas at the well, was placed in a vertical position, and the temperature observed at intervals. When it was found that the temperature had remained constant for two hours, the lower stop-cock was opened for a moment to allow the excess of gas to escape and secure equilibrium between the pressure of the gas inside and that of the atmosphere. At the same time, the temperature and height of the barometer

were recorded. The glass cylinder was then connected with a porcelain tube containing oxide of copper, and already heated to intense redness in a furnace, and the gas forced out of the cylinder by dry mercury. As the gas escaped from the cylinder it was carried through the porcelain tube by a slow stream of nitrogen, previously dried by suitable means.

The gas was thus burned completely to carbon dioxide and water, which were collected and weighed by the usual methods, using a balance plainly sensitive to $\frac{1}{10000}$ gramme.

After the combustion, the glass cylinder was accurately calibrated by means of mercury at a known temperature, and thus was determined the exact volume of gas which had been burned.

As it appears possible under the conditions of the method that some nitrogen might undergo an oxidation, the water produced in the combustion of the gas was carefully tested, but in no case was the water found to have an acid reaction.

In the above described method are determined the weights of carbon and hydrogen per unit-volume of gas. In conducting the combustion, great care was taken to secure complete oxidation of the combustible constituents, and absorption of the products. For the absorption of the water, sulphuric acid of 1·71 specific gravity, followed by phosphoric anhydride, was used, and for the carbon dioxide a solution of caustic potash in glycerine.

For the determination of nitrogen, the following method was employed: A porcelain combustion tube containing oxide of copper was brought to a yellow heat, and a stream of carbon dioxide conducted through the tube until the last traces of air were expelled. The expulsion of the air was considered complete when it was found that the carbon dioxide escaping from the tube was wholly absorbed by a solution of caustic potash—100 cubic centimetres of such gas not leaving a visible quantity unabsorbed by the alkaline solution. Then, after the expulsion of the last traces of air, a quantity of natural gas (100 cubic centimetres were generally employed) was allowed to flow slowly into the stream of carbon dioxide as it entered the combustion tube. In this manner, the gas was burned and a mixture of nitrogen and carbon dioxide collected in an eudiometer or caustic potash solution. After the absorption of the carbon dioxide the volume of the residual nitrogen was measured. This nitrogen was carefully tested for

carbon dioxide, oxygen and carbon monoxide, and was frequently re-passed through the heated combustion tube and again measured, in order to secure the complete combustion of all hydrocarbons. This repetition demonstrated in all but one or two instances that the nitrogen was pure. It was found that with a sufficiently slow stream of gas the oxidation by the oxide of copper is easily rendered complete, although the rate of flow must be regulated with great care.

By the common eudiometric method of analysis no determination is more difficult than that of nitrogen when occurring in small quantities in admixture with hydrocarbons of the paraffin series. In the method above described large quantities of gas can be employed, and the results are accurate.

The determination of free oxygen in natural gas cannot well be made with the quantity of gas commonly at disposal. A test was made in every instance in about 100 cubic centimetres of gas, using an Elliott apparatus, and, as an absorbent, a solution of caustic soda and pyrogallic acid. In all cases the results were negative.

I have found it necessary to conduct the tests for oxygen at the wells, and this was done in the following manner:

A slow stream of gas was caused to flow (directly from the well or main) successively through solutions of caustic potash and pyrogallic acid for ten minutes, in order to expel dissolved air. Then by a simple contrivance the two fluids were mixed without interrupting the current of gas, which continued some time longer through the mixture. If the mixed fluids then exhibited a brown color, gradually increasing in depth, it was considered that the presence of oxygen was established.

The direct determination of free hydrogen has generally been considered a matter of such difficulty that in many published analyses its quantity has been estimated by a calculation based upon the total carbon and hydrogen contained in the gas. For the present purpose a direct determination seemed very desirable, and the process of Hempel has been used in the manner below described: 100 cubic centimetres of gas after the removal of carbon dioxide, were washed with a strong alcohol until the higher hydrocarbons—ethane, propane, etc.,—were removed; this was carried out in an Elliott apparatus having a water-jacket. Then the residual gas mixed with two or three times its volume of

air was passed over asbestos coated with thirty per cent. of palladium sponge, at a temperature of 90° C.

By this treatment the hydrogen alone is burnt, provided the higher paraffins, including ethane, are previously removed by washing with alcohol. From the contraction in volume, after passing the palladium, the proportion of free hydrogen is easily determined. The method is very accurate, when methane is the only hydrocarbon present. It is inaccurate in the presence of ethane and the higher members of the series, and when these are present the washing with alcohol must be long continued. As it is a matter of great difficulty to retain hydrogen, even by the help of the most carefully-ground stop-cocks, the tests for this element were made in all cases at once after the arrival of the samples in the laboratory.

The olefines as a group and carbon monoxide are much more easily determined in natural gas than the paraffins and free hydrogen. The olefines are quickly absorbed and removed by bromine water, and carbon monoxide by a solution of cuprous chloride. These reagents are used in the order named. Unfortunately, however, these fluids are likewise solvents, in less degree for the paraffins—ethane, propane, etc. Hence a gas perfectly free from olefines and carbon monoxide is liable, on being washed with the above-named fluids, to undergo a reduction in volume, leading to a wrong conclusion.

For the determination of these substances the following process was used, based on the solubility of both in a cuprous chloride solution. At the gas well a stream of gas was caused to bubble for two hours or more through 100 cubic centimetres of a solution of cuprous chloride. The solution was preserved for examination in the laboratory.

A quart flask, provided with a glass delivery tube and a funnel tube reaching to the bottom, was filled with boiled water and then the cuprous chloride, prepared as above described, was poured into the flask through the funnel tube. The flask was then heated to the boiling point, and the water caused to boil for three hours. A small quantity of gas was invariably collected from the cuprous chloride solution by this treatment.

The gas so collected was transferred to an Elliott apparatus and carefully tested for olefines and carbon monoxide by bromine

water and cuprous chloride solution. In this way the quantities of these two constituents in a very large quantity of gas could be collected in concentrated form, convenient for a qualitative test.

Carbon dioxide was determined by means of moist potash in an eudiometer over mercury, and also in the Elliott apparatus over water, by caustic potash solution. The latter method yields very correct results.

In addition to the determination carried out in the laboratory, the gas at the well was caused to pass in a slow stream through lime water. The stream of gas was made approximately the same by using the same delivery tube, depth of lime water and shape of containing vessel, and by counting the number of bubbles per minute, and then noting the rapidity with which the lime water became milky. For the detection of ammonia, the gas at the well was caused to bubble through 100 cubic centimetres of water, which had been carefully purified by distilling with addition of sulphuric acid and permanganate of potash. This water was afterwards tested by Nessler's solution, after the common method in use in the examination of drinking water for ammonia.

The presence of exceedingly minute traces of ammonia could thus be shown with great accuracy. As solid masses of ammonium carbonate are reported to have been thrown out from the pipes leading from gas wells in the Murrysville field, this test seemed very desirable.

In the statements of the results of analysis, all gas volumes are to be understood as "normal;" that is, the volumes observed under different conditions of temperature and pressure are all reduced to zero, Centigrade, and 760 millimetres mercury pressure, and where measured in a moist condition are calculated as dry.

The temperatures were all measured by one and the same thermometer, of which the error was known from a comparison with the Yale Observatory standard. This thermometer was made by Green, in New York, and is divided to $\frac{1}{10}$° C.

The barometer used was made by Hicks, and indicated by vernier, changes of $\frac{1}{1000}$ inch. The constant error of this barometer was ascertained by comparison with the standard barometer of the Signal Service Department, in Washington.

In all cases of gas measurements in eudiometers, the observations were made by means of a Grunow cathetometer, having a millimetre scale and reading easily to $\frac{1}{20}$ millimetre.

The etched scales upon the eudiometer tubes, as commonly supplied, are very often incorrect, both as regards uniformity and total length of scale, and are unsuited for accurate measurements of pressure or volumes. The glass cylinders containing the gas samples for combustion were calibrated at a temperature not differing by 1° C. from the temperature at which the gas was measured for analysis. In this way the calculation of errors due to expansion and contraction of the glass vessels was rendered unnecessary. This necessitated repeated calibrations after nearly every combustion.

In the calculation of the results of analyses, the following plan was adopted:

The percentage of carbon dioxide was determined volumetrically. Having failed to find carbon monoxide and olefines in any of the samples, they are necessarily left out of account in the calculation. Having found free hydrogen in only one of the gas samples, and here in traces (Speechley), it is also to be ignored in the calculations.

The quantities of carbon dioxide and water produced in the combustion of a known volume of gas were weighed. From the weight of the water the proportion of hydrogen in a unit volume of gas could then be calculated. The percentage volume of carbon dioxide contained in the gas being known, its weight was deducted from the weight of the total quantity obtained in the combustion. The difference is the quantity corresponding to carbon in the form of hydrocarbons. The nitrogen having been determined in a separate portion of gas, and the free hydrogen being also known, the volume of the hydrocarbons will be expressed by the following equation:

$$\left.\begin{matrix}\text{C and H in form}\\ \text{of hydrocarbons}\end{matrix}\right\} = 100 - (CO^2 + N + H + \text{etc.})$$

That is to say, the actual volume of hydrocarbons will occupy the entire space in the gas not occupied by CO^2, N, and H, O and other constituents of the gas.

No attempt has been made to determine the proportion of individual members of the paraffin series—methane, ethane, propane, etc.—for the reason that no sufficiently accurate methods are known for the estimation of these bodies. No reagent can be named which will absorb and remove from a mixture any one of

these paraffins exclusively, so as to allow of its correct determination by difference.

In such a mixture, moreover, no decided chemical change can be produced in any given paraffin without more or less altering the others. They are remarkable for the resemblance existing between them in chemical relationships, and also for the great resistance which they offer towards reagents of every description, excepting chlorine, which attacks them all readily.

Moreover, a calculation of the relative proportions of the gaseous hydrocarbons of this class, based upon eudiometric data, is only possible where the number of such bodies is known to be limited to two—a condition never to be assumed in a gas of unknown composition.

In illustration of the fact just stated, it may be mentioned that a mixture of one volume each of methane, ethane and propane yields on complete combustion the same products and in the same proportions as three volumes of the intermediate hydrocarbon ethane. This can be shown by a very simple calculation.

SELECTION OF SAMPLES.

It was originally proposed to take samples from mains drawing gas from a group of wells, and in this way obtain an average of the entire group. This was sometimes done, as in the case of the Raccoon Creek and Speechley territories, where a large number of wells, all producing from one sand, are joined to one main. In other fields, the wells are often drilled to different sands, and produce gas from different horizons, as in the case of the Kane wells.

In many cases, among a large number of productive wells, all but two or three are shut in, and are thus held in reserve. In such instances a sample was taken at a single well, and directly from the main at the well.

Of the samples examined, No. 1 was taken at Fredonia, N. Y., by Mr. E. J. Crissey, Secretary of the Fredonia Natural Gas Light Company, from the mains of the company. All the other samples were collected by myself. In view of the great extent of the Pennsylvania gas territory, and the number of small areas of highly productive gas wells, the selection of samples with a view to an approximate average, is a matter of no small difficulty. For the present purpose, and in the absence of scientific criteria, reference

has been made chiefly to the technical importance of certain regions, such as Murrysville and Speechley. Fredonia, N. Y., was chosen, on account of the great depth (geologically) of the gas rock.

Wilcox gas is remarkable for the long maintained high pressure exhibited in certain wells.

Baden and Raccoon Creek lie on the same anticlinal.

Houston (Canonsburg) gas comes from a region 200 miles distant from the far northern Fredonia gas field. All the samples are from regions where natural gas is being largely utilized on account of its fuel value.

DESCRIPTION OF SAMPLES.

No. 1, Fredonia, N. Y. From mains of the Fredonia Natural Gas Light Company, May 12, 1887. Mr. E. J. Crissey, Secretary of this company, furnished the following information: Gas obtained at an average depth of 200 feet. The rock is black and gray shale, alternating, to the depth of about 1,000 feet, where a limestone is found. No gas has been found below 250 feet, until a depth of between 1,700 and 1,800 feet is reached, when gas and salt water are met. At 2,250 feet, gas is again found, which burns with a very white flame, whiter than that of the shallow gas. The sample examined comes from the depth of 200 feet.

Two determinations of nitrogen in this gas gave 9·58 and 9·50 per cent., respectively. Mean, 9·54 per cent.

In two determinations of carbon dioxide there were found 0·38 and 0·44 per cent. Mean, 0·41 per cent.

RESULTS OF ANALYSIS OF FREDONIA GAS.

Nitrogen,	9·54
Carbon dioxide,	0·41
Olefines,	0·
Carbon monoxide,	0·
Free hydrogen,	0·
Ammonia,	0·
Hydrocarbons of the paraffin series,	90·05
	100·00

343·47 cubic centimetres of Fredonia gas yield on combustion, by the method already described—

H^2O — 0·6254 gm.,	corresponding to H, — 0·06964 gm.	= 21·83	per cent.
CO^2 — 0·9144 gm.,	" to C, — 0·24938 gm.	= 78·17	"
		100·00	"

Making allowance for the 9·95 per cent. of nitrogen and carbon dioxide contained in the gas, it is calculated that the 90·05 per cent. paraffins present contain per litre—

0·80627 gm. carbon.
0·22515 gm. hydrogen.

In a second combustion of Fredonia gas, 326·17 cubic centimetres yielded—

H^2O — 0·5927 gm., corresponding to H, — 0·0660 = 21·89 per cent.
CO^2 — 0·8635 gm., " to C, — 0·23552 = 78·11 "
100·00 "

As these quantities of carbon and hydrogen belong exclusively to the paraffins in the gas, it is calculated that the paraffins—amounting to 90·05 per cent. of the total gas—will contain per litre—

0·80185 gm. carbon.
0·2247 gm. hydrogen.

In these calculations, as in the following, an allowance is made in the determination of the carbon for the very small quantity of carbon dioxide, which always occurs in the original gas.

The means of the two results above cited are per litre of paraffins—

0·80406 gm. carbon, = 78·14 per cent.
0·22492 gm. hydrogen, = 21·86 "
100·00 "

In the case of the Fredonia gas, no tests were made at the wells. An actual test made at one of the wells in August, 1884, showed traces of oxygen. In the limited quantity at disposal for the above analyses, no positively certain indication for oxygen could be obtained.

No. 2. From valve house, close to well No. 1, of the Sheffield Gas Company, one-half mile from Sheffield, Warren County, Pa. Wells Nos. 1, 2 and 3 were connected with the main at the time, so that the sample represents the average of the three wells.

Well No. 1 has been flowing since 1875; No. 2 was drilled two years later; No. 3 in 1885. The gas comes wholly from one and the same sand. The record of No. 1 is given on page 23, of Mr. Carll's Report on Warren County, for 1883.

The sand from which these wells produce gas is about 1,400 feet deep, and very nearly at ocean level.

The Sheffield Company owns six wells. In the newer wells, the pressure is even greater than in No. 1. The pressure in No. 1 has remained constant since it was drilled, and amounts to 550 pounds in four minutes, when the gas is shut in.

In the Sheffield region, there are about sixty-four square miles of gas-producing territory, and the gas pressure varies between 500 and 800 pounds per square inch.

The Sheffield gas wells supply Sheffield, Iona, Brookston, Clarendon, Warren, Corry, Erie and Jamestown, N. Y.

The wells in this region have been remarkably persistent.

Determinations of—	(1)	(2)	*Mean.*
Nitrogen, ...	9·00	9·12	9·06 per cent.
Carbon dioxide, . .	0·33	0·27	0·30 "

RESULTS OF ANALYSIS OF SHEFFIELD GAS.

Nitrogen,	9·06
Carbon dioxide,	0·30
Oxygen,	trace.
Hydrogen,	0·
Olefines,	0·
Carbon monoxide,	0·
Ammonia,	0·
Paraffins,	90·64
	100·00

305·27 cubic centimetres of Sheffield gas yield on combustion—

H^2O — 0·4960 gm.,	corresponding to	H, — 0·05523 gm. =	23·36 per cent.
CO^2 — 0·6645 gm.,	"	to C, — 0·18123 gm. =	76·64 "
			100·00 "

From these results, it is calculated that the paraffins present in Sheffield gas contain per litre—

0·65495 gm. caroon.
0·19960 gm. hydrogen.

In a second combustion, 314·44 cubic centimetres of Sheffield gas yield—

H^2O — 0·5090 gm.,	corresponding to	H, — 0·05668 gm. =	23·27 per cent.
CO^2 — 0·6851 gm.,	"	to C, — 0·18684 gm. =	76·73 "
			100·00 "

The paraffins will, therefore, contain per litre—

0·65557 gm. carbon.
0·19887 gm. hydrogen.

The means of these two analyses are per litre of paraffins—

0·65526 gm. carbon,	= 76·69	per cent.
0·19923 gm. hydrogen =	23·31	"
	100·00	"

No. 3. Wilcox well, three miles from Wilcox, McKean County. Sample collected January 29, 1887. Originally known as "Wilcox Well No. 1," now called No. 7.

Was drilled in 1878, and produces gas from the fourth sand, exclusively. This well was the first in this region, and has maintained a continuous pressure of 500 pounds, when shut in. The United Natural Gas Company owns twenty-four wells in the Wilcox field, which occupies an area of about two miles square, No. 1 being in the southwest end. All are very productive, and some are remarkable for unusually high pressures, the gauge registering in one well 900 pounds. All exceed 500 pounds.

Very little salt water is produced. The gas exhibits a decided oxygen reaction, turns lime water rapidly milky, and has a strong odor.

Pipe lines carry the gas from these wells to Bradford, Jamestown, N. Y., Hornellsville, Salamanca and Buffalo, but the supply is largely in excess of the demand at present.

Determinations of—	(1)	(2)	*Mean.*	
Nitrogen, ...	9·32	9·50	9·41	per cent.
Carbon dioxide, . .	0·21	0·20	0·21	"

RESULTS OF ANALYSIS OF WILCOX GAS.

Nitrogen, ...	9·41
Carbon dioxide, ...	0·21
Oxygen, ...	trace.
Carbon monoxide, ...	0·
Olefines, ...	0·
Ammonia, ...	0·
Hydrogen, ...	0·
Paraffins, ...	90·38
	100·00

374·2 cubic centimetres of Wilcox gas yield on combustion—

H^2O — 0·6022 gm.,	corresponding to H_2 — 0·06706 gm.	= 23·48	per cent.
CO^2 — 0·8014 gm.,	" to C_2 — 0·21856 gm.	= 76·52	"
		100·00	"

Hence one litre of the paraffins contains—

0·64622 gm. carbon.
0·19828 gm. hydrogen.

In the case of the Wilcox gas, an accident to some of the sample vessels prevented a second combustion, so that but a single result can be presented.

No. 4. Kane well No. 1, at Kane, McKean County. Gas collected January 30, 1887.

This well was drilled in 1884. The pressure then was 550 pounds when shut in for forty minutes. It was allowed to blow off for eight months and then shut in, when the pressure increased to 630 pounds. This gain in pressure has been permanent up to October, 1886, when the last test was made. The Kane Natural Gas Company owns two other wells in addition to this. The gas exhibits decided oxygen, and carbon dioxide reaction.

Determinations of—	(1)	(2)	*Mean.*
Nitrogen,	9·67	9·91	9·79 per cent.
Carbon dioxide,	0·20	0·20	0·20 "

RESULTS OF ANALYSIS OF KANE GAS.

Nitrogen,	9·79
Carbon dioxide,	0·20
Oxygen,	trace.
Olefines,	0·
Carbon monoxide,	0·
Hydrogen,	0·
Ammonia,	0·
Paraffins,	90·01
	100·00

349·03 cubic centimetres of gas yield on combustion—

H^2O — 0·5600 gm., corresponding to H, — 0·06236 gm. = 23·18 per cent.
CO^2 — 0·7580 gm., " to C, — 0·20672 gm. = 76·82 "
100·00 "

Hence one litre of the paraffins contains—

0·65801 gm. carbon.
0·19849 gm. hydrogen.

248·1 cubic centimetres of the same gas yield on combustion—

H^2O — 0·3987 gm., corresponding to H, — 0·04439 gm. = 23·28 per cent.
CO^2 — 0·5366 gm., " C, — 0·14634 gm. = 76·72 "
100·00 "

Hence the paraffins of Kane gas contain per litre—

0·65537 gm. carbon.
0·19883 gm. hydrogen.

The means of these two analyses are per litre of paraffins—

0·65669 gm. carbon,	=	76·77 per cent.
0·19866 gm. hydrogen,	=	23·23 "
		100·00 "

No. 5. Speechley. This field has been a remarkably productive one, as regards quantity and pressure of gas and number of wells. These wells are situated on a northeast and southwest line, about six miles southeast from Oil City.

The sand rock from which the gas is obtained averages 1,900 feet in depth, and is about 900 feet below the third oil sand of Venango County. This latter sand also produces gas, but in much smaller quantity, and it is consequently, cased off, so that the gas in this territory is wholly obtained from one and the same sand rock. The Northwestern Gas Company, of Oil City, have sixty wells, and a large number of wells are owned by other companies.

The samples of gas for examination were taken April 13, 1887, from the high-pressure main at South Oil City, belonging to the Northwestern Natural Gas Company. At this time the pressure in the main was 100 pounds.

This sample may be considered to represent approximately the average of the gas from a large number of wells.

The tests at the main indicated the presence of oxygen, but less of carbon dioxide than found in the Warren and McKean County gas.

Determinations of—	(1)	(2)	*Mean.*
Nitrogen,	4·61	4·41	4·51 per cent.
Carbon dioxide,	0·05	0·05	0·05 "
Hydrogen,	0·02	0·02	0·02 "

RESULTS OF ANALYSIS OF SPEECHLEY GAS.

Nitrogen,	4·51
Carbon dioxide,	0·05
Hydrogen,	0·02
Carbon monoxide,	0·
Olefines,	0·
Oxygen,	trace.
Ammonia,	0·
Paraffins,	95·42
	100·00

304·24 cubic centimetres of Speechley gas yield on combustion—

H^2O — 0·5423 gm., corresponding to H, — 0·06039 gm. = 22·93 per cent.
CO^2 — 0·7441 gm., " to C, — 0·20293 gm. = 77·07 "

100·00 "

Hence the paraffins of this gas contain per litre—

0·69900 gm. carbon.
0·20801 gm. hydrogen.

In a second combustion of the same gas, 310·52 cubic centimetres yield—

H^2O — 0·5500 gm., corresponding to H, — 0·06125 gm. = 22·85 per cent.
CO^2 — 0·7585 gm., " to C, — 0·20686 gm. = 77·15 "

100·00 "

Hence the paraffins contain per litre—

0·69815 gm. carbon.
0·20671 gm. hydrogen.

The means of these two results are per litre of paraffins—

0·69857 gm. carbon, = 77·11 per cent.
0·20736 gm. hydrogen, = 22·89 "

100·00 "

No. 6. Hukill well, on the Dick farm, Lyon's Run District, southern end of Murrysville field, and one of the sixty wells belonging to the Philadelphia Company.

This well was drilled in 1883, and was allowed to blow off for a long time. The well is very productive, and has a pressure as it flows through the main of 285 pounds.

The well has extra-heavy casing, and there is good reason to suppose that the gas comes exclusively from the Murrysville sand. The sample was taken April 8, 1887. The gas produces a decided carbon dioxide reaction, but exhibits a very slight reaction for oxygen.

This gas has a very faint odor, free from the pungent character noticed among some of the gas samples.

The well yields no oil, but a very little salt water.

Determinations of—	(1)	(2)	*Mean.*
Nitrogen, ...	2·13	1·91	2·02 per cent.
Carbon dioxide, . .	0·26	0·30	0·28 "

RESULTS OF ANALYSIS OF MURRYSVILLE GAS.

Nitrogen,	2·02
Carbon dioxide,	0·28
Oxygen,	trace.
Carbon monoxide,	0.
Olefines,	0·
Ammonia,	0·
Hydrogen,	0·
Paraffins,	97·70
	100·00

346·94 cubic centimetres of Murrysville gas yield on combustion—

H^2O — 0·5473 gm., corresponding to H, — 0·06095 gm. = 25·06 per cent.
CO^2 — 0·6682 gm., " to C, — 0·18224 gm. = 74·94 "
100·00 "

Hence the paraffins in Murrysville gas contain per litre—

0·53763 gm. carbon.
0·17981 gm. hydrogen.

In a second combustion, 306·28 cubic centimetres of gas yielded—

H^2O — 0·4818 gm., corresponding to H, — 0·05363 gm. = 25·02 per cent.
CO^2 — 0·5895 gm., " to C, — 0·16074 gm. = 74·98 "
100·00 "

Hence the paraffins contain per litre—

0·53718 gm. carbon.
0·17922 gm. hydrogen.

The means of the above analyses are per litre of paraffins—

0·53741 gm. carbon, = 74·96 per cent.
0·17950 gm. hydrogen, = 25·04 "
100·00 "

(*To be continued.*)

[*Contribution from the Department of Dynamics, University of Penna.*]

EXPERIMENTAL VERIFICATION OF WEISBACH'S THEORY OF IMPACT OF WATER UPON PLANE SURFACES.

By W. C. Smith, Jr., and Franklin Sheble.

INTRODUCTION.

The following series of experiments, made for the purpose of verifying laws of hydraulics, stated in *Weisbach's Mechanics of Engineering*, first volume, will prove of interest, as giving additional data in a direction which has received very little attention from experimenters, and also as proving the coefficient of efflux, usually adopted to be too small for the form of mouth-piece used.

Wm. D. Marks, Ph.B., C.E.,
Whitney Professor of Dynamical Engineering.

DESCRIPTION OF APPARATUS USED.

The Mouth-piece.—This was a circular orifice, of ½″ diameter, in a thin brass plate $\frac{1}{16}$″ thick by 3″ x 2½″. For such an orifice, Weisbach gives (p. 825) as a coefficient of efflux, ·626. We, by accurate experiment (described below), found this to be much too small. Under a head varying from 2·541′ to ·541′, the coefficient of efflux, with but one exception, remained unchanged to the

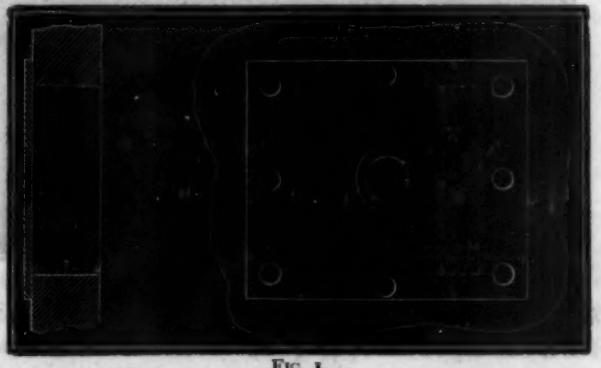


Fig. 1.

hundredths' place, and in the thousandths' changed from 1 to 2 and back again. This coefficient generally had the value ·712. The mouth-piece is shown in section in *Fig. 1*. The hole was bored with ½″ tool, and then reamed out with a larger one.

The Vessel used as a Water Tank.—This was a large barrel, giving as maximum head of water 2·541′. At the height of the different heads desired, above the orifice, overflow holes were bored, thus enabling the heads to be kept constant. The mouth-piece was placed upon the barrel, so as to be very approximately in a vertical plane. The size (2½″ diameter) of the orifice in the side of the barrel leading to the circular mouth-piece was so great compared with that (½″ diameter) of the actual orifice, as to exert no influence in over-contracting the effluent stream. The water was supplied to the barrel through a hose connected with the city mains.

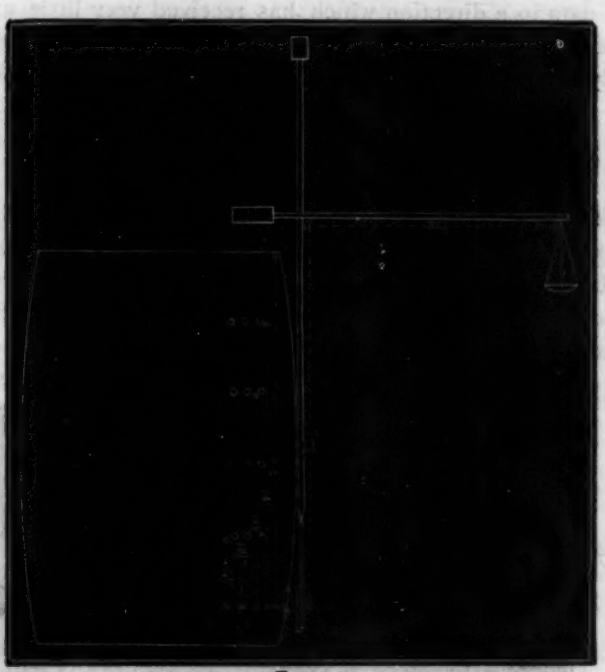


FIG. 2.

The Apparatus for Measuring the Strength of Impact.—This consisted of a bell-crank lever (*Fig. 2*), with arms 22½″ and 33½″ in length, and accurately counter-balanced. The arrangement for reducing the friction was not so good as might have been desired, for the lever, although supported somewhat above its centre of gravity, had a tendency to remain in any position in which it might be placed.

At the end of the longer arm, and fastened to it through the centre of pressure, was the surface impinged against by the effluent water. This was a board $4'' \times 4'' \times \frac{1}{4}''$, polished very smooth, so so that the force exerted on it should be that of the impact alone. (*Fig. 3.*)

In measuring the impact, the scale pan at the end of the $22\frac{1}{2}'$ arm was gradually loaded, until the surface struck the stream of water, and the weights were then increased, until the vertical arm came into coincidence with a plumb line hung from the supporting point of the lever. In this position, the mouth-piece

FIG. 3.

being vertical and very close ($1''$) to the surface, the axis of the stream was perpendicular to the surface as required. In bringing the surface to this position, it will be observed that the tendency of the friction of the lever was to increase the weight required in the scale pan. Accordingly, we see that the experimentally determined impact (vertical Column 4, Table III) is greater than that determined from the values of Q and c, corrected for the mouth-piece used (vertical Column 3, Table III), *i. e.*, greater than the theoretical values. This excess is also otherwise

accounted for in *Weisbach*, p. 1009, lines 21–24. It is probably due partly to each influence.

Consulting Columns 3 and 4, Table III, it is seen that the difference between the actual impact and the experimental impact is not constant, but decreases with the head. This shows that the friction of the machine, and the lengthening of the lever arm by the falling back of the water, and consequently their influence are decreased by shortening the head. It was for this reason, *i. e.*, influence of head, that we were unable to calculate and allow for the actual amount in ounces of the effect of friction, and of the length ening of the lever arm by the falling back of the water.

THE COEFFICIENT OF EFFLUX.

The method of finding the coefficient of efflux, μ, of the orifice was as follows: A cylinder of volume $V = .9303$ cubic foot was used to receive the water as it flowed unimpeded from the orifice. The time in seconds necessary to fill this vessel, with water flowing from the orifice with the velocity c_1, corresponding to the different heads (Column 1, Table I) is given in Column 2, Table I. The mean values of these observed times are given in Column 3, Table I. In Column 4, we have the actual amounts of water in cubic feet issuing from the orifice per second under the different heads. These are obviously V/t; t denoting the number of seconds required to fill the vessel V. In the fifth column we have the actual velocity with which the water leaves the orifice $= c_1 = Q_1 \div F$, Q_1 being obtained as in Column 4, and F representing the area in square feet of the orifice of $\frac{1}{2}''$ diameter. For comparison, in the sixth column, are given the purely theoretical values in feet per second of the velocity of the effluent water, $c = \sqrt{2gh}$. In Table II, are tabulated the coefficients of efflux for the circular orifice $\frac{1}{2}''$ diameter. In the first column are given the heads, in the second the purely theoretical quantity of water flowing out per second, calculated from the formula $Q = Fc = \sqrt{2gh}$, F and c having the same significance and values as in Columns 5 and 6. Table I, Column 3, is merely a reproduction of Column 4, Table I. In Column 4, Table II, are given the coefficients of efflux of the orifice for the different heads. The value of μ, for $h = 2.041'$, is most unaccountably smaller than any of the others. These values of μ will be used (Column 3,

Table III) in calculating the actual impact against the surface. It is allowable to do this, for Weisbach, in deriving his theoretical formula $P = c\ Q\ \gamma/g = 2\ F\ h\ \gamma$, pre-supposes that the coefficient of efflux = 1, a case never realized in practice.

TABLE I.

For a Circular Orifice, ½ Inch in Diameter, in a Thin Plate.

V = ·9303 cubic foot. F = ·00136 square foot.

Head in Feet.	Time in Seconds.	Mean Time in Seconds $= t$.	Practical Q in Cubic Feet $= Q_1$ $Q_1 = \frac{V}{t}$	Real Velocity of Efflux in Feet $= c_1$ $c_1 = \frac{Q_1}{F}$	Theoretical Velocity of Efflux in Feet $= c = \sqrt{2gh}$
2·541	74½ 75 75	75″	·0124	9·117	12·79
2·041	83 84½ 83	85″	·0109	8·014	11·47
1·541	95 97 93 100 97	96″4	·0096	7·058	9·937
1·041	117½ 118 117	117″5	·0079	5·808	8·161
·541	163 164 160 164	163″	·0057	4·191	5·882

TABLE II.

For a Circular Orifice, ½ Inch in Diameter, in a Thin Plate.

F = ·00136 square foot.

Head in Feet.	Theoretical Q in Cubic Feet $= Q$. $Q = F\sqrt{2gh}$	Practical Q in Cubic Feet $= Q_1$. (From Table I.)	Coefficient of Efflux $= \mu$ $\mu = \frac{\text{Practical } Q}{\text{Theoretical } Q} = \frac{Q_1}{Q}$
2·541	·0174	·0124	·712
2·041	·0156	·0109	·699
1·541	·0135	·0096	·711
1·041	·0111	·0079	·712
·541	·0080	·0057	·712

EXPLANATION OF THE TABLES.

Table I.—This has been already explained.

Table II.—This has been already explained.

Table III.—In this table, the first column contains, as usual, the different heads. In the second are given the purely theoretical impacts calculated from the formula in *Weisbach*, p. 1008. These are merely given for comparison, having no meaning other than that expressing the depressing influence of the orifice on the quantity Q. In Column 3 are given the impacts in ounces, calculated with reference to the actual values Q_1 and c_1 of Q and c. In the fourth column are given the impacts indicated by the lever and scale pan, and these are larger than those in the preceding column, as explained above.

Table IV.—This contains the result of experiments with a bounded surface. The first column gives the heads in feet. The second contains merely the values of Column 2, Table III, multiplied by 2, and the third those of Column 3, Table III, multiplied by 2. The fourth column is Column 4, Table III, multiplied by 2, and the fifth and sixth columns contain the experimental values of the impact against two bounded surfaces of different dimensions.

Table V.—Explains itself.

TABLE III.

For a Circular Orifice, ½ Inch in Diameter, in a Thin Plate.

Impact against a Plane Surface.

$Q_1 = \mu\, Q.$

Head in Feet.	Theoretical Impact in Ounces. $J = 2\,F\,h\,\gamma = \frac{c}{g}\,Q\,\gamma$	Actual Impact in Ounces, Using c_1 and Q_1, from Table I. $J_1 = \frac{c_1}{g}\,\mu\,Q\,\gamma = \frac{c_1}{g}\,Q_1\,\gamma$	Experimental Impact in Ounces. $= I_2$.
2·541	6·91	3·51	3·94
2·041	5·55	2·71	3·18
1·541	4·19	2·10	2·35
1·041	2·83	1·42	1·59
·541	1·47	·74	·92

TABLE IV.

For a Circular Orifice, ½ Inch in Diameter, in a Thin Plate.
Impact against a Bounded Surface.

Head in Feet.	Theoretical Impact in Ounces. $= 2f = f_0 = 4Fh\gamma = \frac{2c}{g} Q\gamma$.	Actual Impact in Ounces $= 2f_1$. $f_{10} = \frac{2C}{g} \mu Q\gamma = \frac{2C}{g} Q_1\gamma$	Experimental Impact in Ounces. (From Table III.) $f_{10} = 2f_2$.	Experimental Impact in Ounces against Surface 2 1-16 Inches Diameter and 9-16 inch Deep.	Experimental Impact in Ounces against Surface 1½ inches Diameter and ½ inch Deep. Being one-half Size of that in Art. 501.
2·541	13·82	7·02	7·88	7·81	7·64
2·041	11·10	5·42	6·36	6·30	6·13
1·541	8·38	4·20	4·70	4·62	4·53
1·041	5·66	2·84	3·18	3·11	3·11
·541	2·94	1·48	1·84	1·76	1·76

TABLE V.

For a Circular Orifice, ½ Inch in Diameter, in a Thin Plate.
Showing Relation between Experimental Impacts against Plane and Bounded Surfaces.

Head in Feet.	Experimental Impact against a Plane Surface.	Experimental Impact against a Bounded Surface, 2 1-16 inches Diameter and 9-16 inch Deep.	Experimental Impact against a Bounded Surface, 1½ inches Diameter and ½ inch Deep. (One-half Size of that used in Art. 501.)
2·541	1·	1·98	1·94
2·041	1·	1·98	1·93
1·541	1·	1·97	1·93
1·041	1·	1·96	1·96
·541	1·	1·91	1·91
		mean, 1·96	mean, 1·934

These tables, whose accuracy we can vouch for, seem to show beyond all doubt, that Weisbach's theory of impact, if the influence of the mouth-piece be allowed for, is practically true as well as theoretically.

[*Contribution from the Dept. of Civil Engineering, University of Penna.*]

IMPROVEMENT OF TIDAL RIVERS.

By Lewis M. Haupt, A.M., C.E., Professor of Civil Engineering.

By the improvement of rivers is meant the removal of any or all obstructions to navigation, as bars, reefs, ledges, snags, bowlders, bends, wrecks, etc. It consists, in fact, in the rectifying and deepening of the channel to such an extent as to adapt it to meet the requirements of commerce. The engineer must therefore ascertain what these requirements are, as well as the character and cause of the obstructions, before he can apply the remedy. This involves a thorough survey and study of the physical features of the stream, the determination of its velocities, measurement of its volume, and sections and location of its thalwegs, that the conditions of its discharge may be known.

Since, in alluvial bottoms, bars form the chief obstructions, an investigation into their cause becomes of fundamental importance. As a basis for this investigation, it may be accepted as a maxim that *if the bottom velocity of a stream be increased to the limit required by the material, it will scour; if diminished, it will deposit,* hence whatever tends to increase its energy at any point, will prove beneficial at that point, and whatever tends to diminish it will be injurious. The energy being a function of the mass into the square of the velocity, and the mass being constant, it follows that the bar-building or bar-destroying agencies vary as the squares of the velocities, hence the importance of maintaining a uniform velocity sufficient to prevent the formations, or secure the removal of bars.

But the tendencies of flowing water are in the opposite direction, or towards impulsive movements. In moving down a uniform slope the velocity is augmented until it may become sufficient to move the material composing the bed. This is then pushed or rolled along, until a low dam is built up, which checks the velocity and forms a pool over the crest of which the water escapes, only to repeat the operation. Thus the profile of the bed of a stream will be found to be a succession of hills and hollows, with the more gentle slopes on that side of the crests from whence came the

material. The velocity is also affected by the volume of water passing a given section in a given time, or the prism of discharge; by the area of the section; by the form and material of the channel, and by other conditions, all of which must be considered in any attempt to modify the action of the currents at any point.

BARS.

In tidal waters the problem becomes more complicated, in consequence of the opposing forces of the flood and ebb tides flowing often in different channels and with constantly varying velocities. In straight reaches of the river bed, the paths of flow will be coincident, but in reverse curves it is evident that the momentum of the flood will tend to impel it against one bank, whilst that of the ebb will force it to the opposite side, thus separating the paths of the resultants and leaving between them a line of lower velocity where a bar will ultimately form. This may be called a *cross-over bar*. Again, where the water passes from a contracted or narrow section of its bed to a wider section without a corresponding increase of volume, there will be a dispersion of its energy and reduction of velocity, causing a precipitation which may be designated as an *expansion bar*.

A *confluent bar* is one invariably found at the junction of two streams, where the velocity of one is checked by the inertia of the other. These bars will vary in size and position according as the angle between the axes of the streams vary. They are also affected by the relative volumes of the streams.

A fourth cause for the formation of bars is found in the loss of velocity, due to a change of direction. At every bend, below the convex bank, there will be found more or less of a deposit. In tidal rivers, it is often visible, both above and below the turn. These formations may be termed *elbow bars*.

Such are the principal causes of bars, and they at once suggest the correspondent remedies. Thus, to remove *cross-over bars*, both tides should be made, if possible, to flow in the same path, or the volume of either prism should be modified by regulating works, properly located. *Expansion bars* may be prevented or removed by contractions by lateral dikes or by canalization. *Confluent bars*, by contractions over limited areas, by closing lateral channels, usually at the upper end, or by a change in the direction of the

axis of either stream, where possible. *Elbow bars* are not serious obstructions, but where necessary, they may be partially removed by wing dams.

Dredging cannot be expected to produce permanent results, except where there are auxiliary works to change the regimen of the stream and increase the bottom velocities over the area dredged. It follows from the above, that jetties or bulkheads, which are so located as to change the direction of a stream *abruptly*, whether in a river or harbor, will produce elbow-bars and so prove injurious when placed in or near the channel to be created. Such jetties are usually built in pairs to defend the artificial channel dredged between them, and at an angle to the path of the current, in which case they form slackwater pools for the accumulation of silt, which requires to be frequently removed. Instead of increasing the velocity of the stream, they act as obstructions to the currents and tend to diminish the velocities both above and below them, forming bars.

It has been frequently noted by the most casual observer, that the deep-water channel of a river is to be found near to the concave bank, at the bends. This is due to the "head" produced by the momentum, which piles the water up on that side, and also to the increased velocity of that portion of the stream, since it traverses the longer path. This effect is, therefore, produced by the form of the bank, which *reacts* on the stream, throwing it back upon itself and changing its direction, and the same results may invariably be produced by similar artificial forms of construction, which I would designate as *reaction dikes*, placed adjacent to the bars to be removed, to distinguish them from deflecting dikes, located at a distance from the site to be improved.

Before proceeding to a consideration of any particular river as a whole, it should be further noted that, as a rule, the *flood* tide is the bar-building and the ebb the bar-destroying agent. For, as the flood rolls up, it must retard, stop and reverse the movement of the ebb augmented by the land drainage; its waters are heavier than those of the ebb under which it flows as a wedge, lifting them to the surface, so that whilst the bottom currents are running *up* stream on the surface, the ebb continues flowing *down* for nearly an hour after the lowest water has been observed. This is shown by the rapid rising of the water on the gauge—for

a foot or over—in mid-stream, before the surface currents are reversed.

It is this submerged flood action wedging its way up stream, resisted and forced under by the weight of the superincumbent ebb, which displaces the sand and silt of the bed of the river, and where the resultant of the ebb discharge does not effect its outflow over the same path, there the deposit is left and a cross-over bar formed.

Again, wherever a salient or projecting bank occurs, flanked by reverse curves, it will be found that the loci of the flood and ebb resultants will be separated, the former hugging the convex bank, against which it impinges, on the down-stream side, and under which it scours a channel, gradually diminishing in depth to a point just below the elbow; thence it crosses to the concave bank above the bend, with a steeper slope, leaving below it two well-defined channels, with a submerged spur, or often an island, between them. The one on the convex is the flood, whilst that on the concave bank is the ebb channel. When these can be made to coincide, deeper water will be the result.

PHYSICAL CHARACTERISTICS OF THE DELAWARE RIVER.

The application of these principles becomes manifest at once by reference to the accompanying plan and profile of the Delaware River. By an inspection of the plan, it will be seen how readily the location of the bars may be determined. Passing up stream from the head of the bay below Reedy Island, we find a long straight reach succeeded by a double flexure, causing the paths of the flood and ebb to diverge and forming the cross-over bar at Reedy Island.

The broken line on the chart indicates the location of the thalweg or line of deepest water, which is sometimes in the ebb channel and at others in the flood. The figures indicate the depths in feet below mean low water, as determined by the United States Coast Survey of 1840–44, and subsequently.

In approaching Reedy Island, the direction of the flood resultant is such as to intersect the shore just below Port Penn (see chart), where it is compressed into the narrow channel back of the island, producing a depth of thirty feet. Thence it proceeds close along shore with decreasing depth to Reedy Point, where there are but

six feet just below the point; then a steep descent to twenty-five feet in the ebb channel beyond. Between the flood channel on the left and the ebb flowing under Elsingborough Point lies the bar of which Reedy Island forms a part. On the opposite or convex bank of the river and protected from both flood and ebb by Stony and Elsingborough Points, are seen the elbow bars, known as Stony Point and Dan Baker Shoals. This latter being near mid-river, is a dangerous obstruction, and works are now being executed for its removal, at an estimated cost of $324,000. The original plan to build a concave dike, about 25,000 feet long, or nearly five miles, from Reedy Island to a point on the right bank below Blackbird Creek, has been modified so as to leave the lower end open to provide for navigation. Such a dike will, no doubt, reduce the flood velocities behind the island and thus increase the elbow bar at Reedy Point. This will in turn deflect somewhat more of the ebb, causing it to act more directly upon the shoal. By this indirect application and at a large expense, it is hoped that a sufficient scour will be effected. The difficulties of securing a foundation for the dike in the semi-fluid mud at this locality are very great, and it is reported that solid bottom lies at a depth of ninety feet below the surface. About 2,000 feet of this work is under construction. It is my impression that by a more direct application of the ebb, the resultant of which lies to the east of the axis of the river, by means of a reaction dike, located between the Dan Baker Shoal and Alloway's Point, which would be only about one-third as long and cost correspondingly less, a better result would be obtained.

In the next reach of the river, from Reedy Point to New Castle, the same features occur in reverse order. Here, the flood is the eastern and the ebb the western channel; the elbow bars are found at Goose Island Flats, and the cross-over bar in the Pea Patch Island and Bulkhead Shoals.* Here, also, is seen an *expansion* bar, known as the Middle Ground, due to the abnormal width of the river at this bend. The dikes proposed by the Board of Engineers for the improvement of the east channel are represented by the dotted lines on the chart. The one, extending from the island

* It was here that in 1873 the writer established the lines and surveyed the sites for the first range lights located and built upon the Delaware, under the direction of General Wm. F. Raynolds, United States Light-House Engineer.

"up stream in a curved line approximately parallel to the New Jersey shore opposite—14,000 feet, or less, in length," it is estimated, will cost about $231,000. The cost of dredging at this locality, to give a channel 26 by 600 feet, is estimated at $88,020.*

From New Castle up, the river is nearly straight for about thirteen miles, but it varies in width through a range of about 100 per cent. At the widest part is seen the Cherry Island Flats, which is an expansion bar. The crest at the lower end of the western channel has been dredged to a depth of 24 feet, width of 400 feet, and length of 2 miles, between the years 1880 and 1884, at a cost of nearly $400,000, and is more nearly self-sustaining than any other work of a similar character on the river, as it lies in the path of both flood and ebb currents. The tendency of the river to build a bar on the north side would indicate that the southern channel were the better one to improve with a view to permanence. The Marcus Hook Bar, at the upper end of the straight reach, is virtually an elbow bar formed by the flood above Old Man's Point, and is out of the way of navigation. Just beyond this, however, occurs the rocky shoal known as Schooner Ledge. As this is rock, its presence is not due to the action of the river; its removal by blasting has already been in large part completed, and it is permanent. The estimated cost of its total removal to twenty-six feet depth is about $450,000.

Cherry Island is an elbow bar, produced by Thompson's Point, whilst the middle grounds of Little Tinicum and Maiden Islands with the Fort Mifflin Bar are combinations of cross-over and elbow bars, producing one of the most difficult sections of the river to improve. On the bar separating the ebb and flood channels, there was originally but seventeen feet of water. "Dredging was begun in 1873, and has continued at intervals ever since, but the river has not been able to maintain the depth so gained." The cut was nearly a mile long and 400 feet wide and had cost, up to 1885, $281,784. During 1885, 96,145 cubic yards more were removed and deposited behind the brush and stone dike, then under construction between Hog and Maiden Islands. "The filling seems to have been the result * * * partly of the washing in of sand by the flood current which passes up the channel behind

* From the *Preliminary Report of the Board of Engineers, U. S. A.*, dated Philadelphia, Pa., January 23, 1885.

Tinicum Island and crosses the line of the cut diagonally." It is to cut off this drift that the present dike, 7,000 feet long, is being built to mean low water.

At the entrance to the Schuylkill there is found the usual confluent bar, which has been frequently dredged and as frequently filled up. Above this, within the limits of Philadelphia, are the horse-shoe, chiefly an elbow bar; Smith's and Windmill Islands, cross-over; Richmond or Petty's Island, an expansion bar, and Five Mile, a cross-over and elbow bar. This last-named obstruction is so marked in growth and so serious a barrier that it forms the upper limit to deep draught vessels, and is the controlling feature in all up-river navigation. But for this bar there could readily be maintained a sixteen foot navigation almost to Trenton, or at least to Bordentown. Its partial removal therefore becomes an important matter in the permanent improvement of the river, and it is my purpose to give it detailed study, the results of which I hope to submit hereafter.

The remaining up-river bars, with their characteristics and possible remedies, may be readily traced from the plans and profiles of the river. In these thirty miles, it will be observed how the intermittent movement of the stream moulds the bottom thalweg into gentle up- and steeper down-river slopes. The Five Mile Bar is an exception, and indicates that the movement is in the opposite direction.

SUMMARY OF IMPROVEMENTS BELOW PHILADELPHIA.*

The original obstructions at Mifflin Bar reduced the depth to seventeen feet; at Schooner Ledge and Cherry Island Flats, to eighteen; at Bulkhead and Dan Baker Shoals, to about twenty feet, M.L.W.

"The efforts of the past to improve the river between Philadelphia and the bay have been confined to dredging, except at Schooner Ledge, where solid rock has been removed."

"The entire amount expended on the improvement of the Delaware River, from 1836 to June 30, 1885, was $1,364,746.87, of which $45,000 was expended on that part of the river between Trenton and the upper part of Philadelphia."

"During the fiscal year ending June 30, 1886, the sum of

* Extract from *Report of the Chief Engineer, for 1886.*

$134,971.05 was expended in surveying," dredging and dike construction.

Of the various channels dredged, some were entirely obliterated within a year, and others are slowly but surely filling. The only permanent work has been the partial removal of Schooner Ledge to twenty-four feet, M.L.W. Hence in fifty years there have been expended in dredging, surveying and diking (deducting the $170,000 spent on Schooner Ledge and $40,000 for up-river), $1,284,717.92, and in January, 1885, a board of engineers, appointed to prepare plans and make an estimate for the permanent improvement of the river, reported that the formation of a ship channel, having a least width of 600 feet and a depth of 26 feet, M.L.W, "by means of dikes, with recourse to dredging where necessary, as an aid to such contracting and regulating works," would cost about $2,425,123 for the lower portion of the river. The cost of the maintenance of these works is estimated at $87,206, which is but 3·6 per cent., and the interest of the capital at four per cent., is $97,005.92, making the total annual expense $184,211.92, as compared with $268,439, the estimated annual cost of dredging. No limit of time can be fixed within which the results may be secured. The report also adds that "regulating works, if their positions are properly marked, are an aid to navigation."

As to the efficiency of the two methods, by dredging or by diking, there can therefore be no question unless the cost of dredging can be reduced to a small percentage of that used as a basis in the estimate, and this, I believe, can be done at some localities by utilizing the surface velocities with current deflectors, which are found to be very rapid and effective. But even without such a current-dredge, the magnitude of the interests involved is so great as to require the critical study of each site with a view to the selection of that form, size and position of dike which will give the best results with the least expense for cost and maintenance. Such an effect, I believe, can be secured by a *reaction dike* built in the form of a reverse curve or ogee, properly located with respect to the currents, and so placed as to compress and concentrate the ebb locally upon and carry it over the obstructing bar.

The use of dikes, as generally applied, is but a feeble, indirect and expensive way of applying the principle of current

scour. It acts over large areas, and is very slow in its operation, sometimes requiring scores of years, whereas the local construction should be more efficient and immediate for the reasons stated.

WAS PHILIP REIS THE INVENTOR OF THE ARTICULATING TELEPHONE?

BY PROF. EDWIN J. HOUSTON.

There appeared in the January number of the JOURNAL OF THE FRANKLIN INSTITUTE, for 1887, a short article by me, entitled "Can the Original Reis Telephone transmit Intelligible Articulate Speech?" In this article was published some correspondence from Dr. Theodore Stein, of Frankfort-on-the-Main, in reference to certain experiments made by Mr. Jno. R. Paddock with old and original Reis instruments. In this correspondence, Dr. Stein denies that the apparatus in question can transmit articulate speech, but acknowledges that certain other forms of Reis apparatus can transmit intelligible words or short sentences.

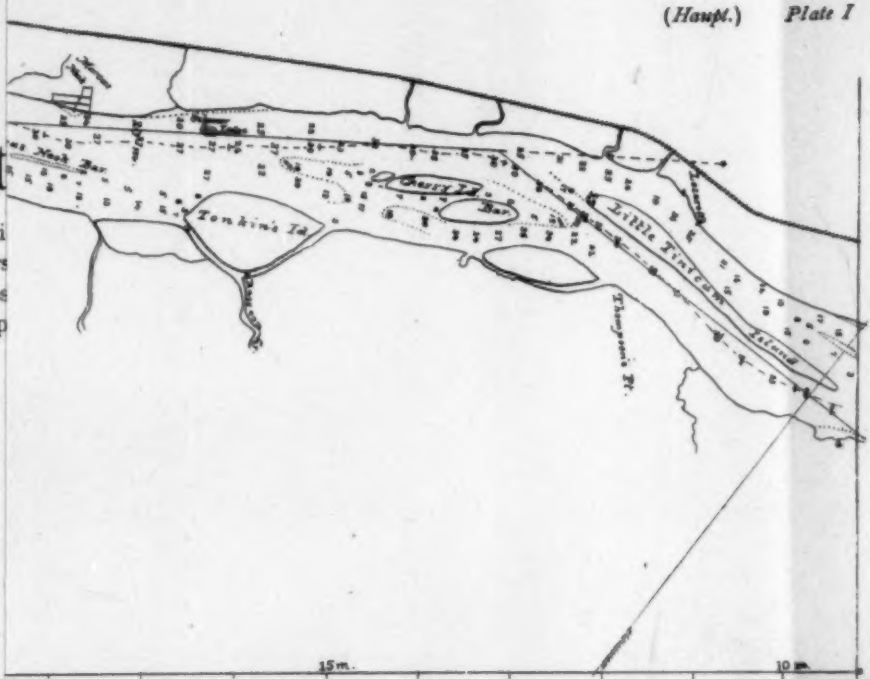
Dr. Stein has published in the *Electrician and Electrical Engineer*, for July, 1887, an open letter to me, which I have only just seen, since its author omitted sending me a marked copy of the same, and since he preferred to publish his letter in a different journal from that in which my article appeared. It is true that I am a subscriber to the excellent journal in which Dr. Stein's open letter appeared, yet, from great press of professional work, my journals had accumulated during the summer, unread, in a manner which I am sure not infrequently happens to busy men. I have therefore only just seen Dr. Stein's letter, and if it has remained unanswered so long, he has only himself to blame therefor.

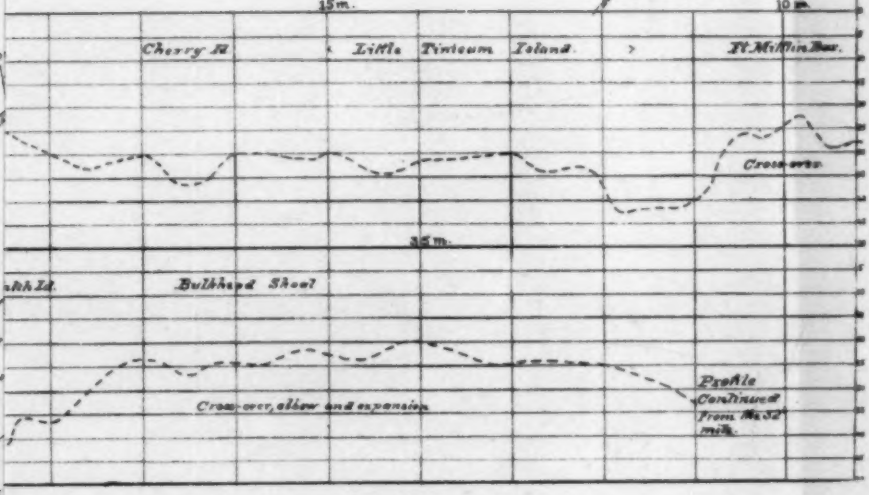
Since Dr. Stein has chosen the form of an open letter, I may perhaps be pardoned for replying in this somewhat questionable style of conducting a scientific controversy.

PHILADELPHIA,

To Dr. Theodore Stein: September 14, 1887.

It is only at this late date that your open letter to me of May 25, 1887, has come to my notice. Had you seen fit to publish the same in the JOURNAL OF THE FRANKLIN INSTITUTE, in which the statements to which you object


Cherry Id.
Bar
Tonkin's Id.
Little Tinicum Island
Thompson's Pt.


15m.
10m.
Cherry Id.
Little Tinicum Island
Ft. Mifflin Bar.
Crossover.
35 ft.
Bulkhead Shoal
Crossover, elbow and expansion.
Profile Continued From Ms 52 mile.

PLAN AND PROFILE

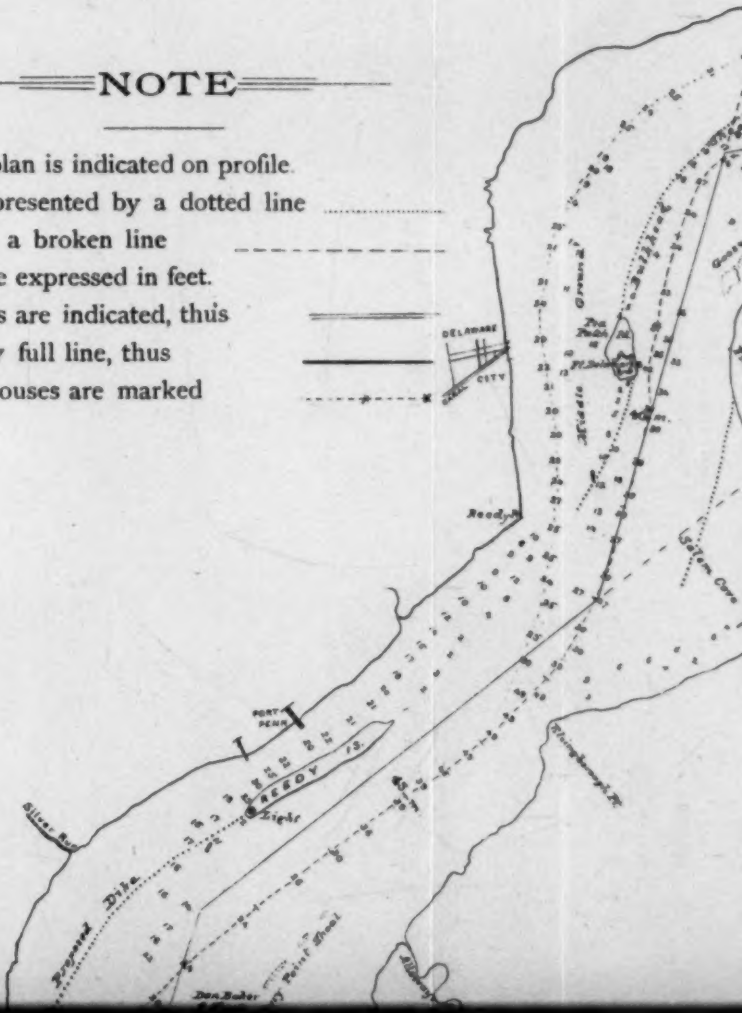
OF THE

Delaware River from the Bay to Trenton

SHOWING the position of the thalweg, or deepest water line, with depths below mean low water; the bars, islands, elbows, ranges and other obstructions and aids to navigation, and the proposed location of dikes for the permanent improvement of the river, as projected by a Board of Engineers.

NOTE

The scale of the plan is indicated on profile.
The dikes are represented by a dotted line .....
The thalwegs by a broken line - - - - - - - -
The soundings are expressed in feet.
Dredged Channels are indicated, thus ═══
Dikes by a heavy full line, thus ———
The range light-houses are marked .....×



COMPILED BY

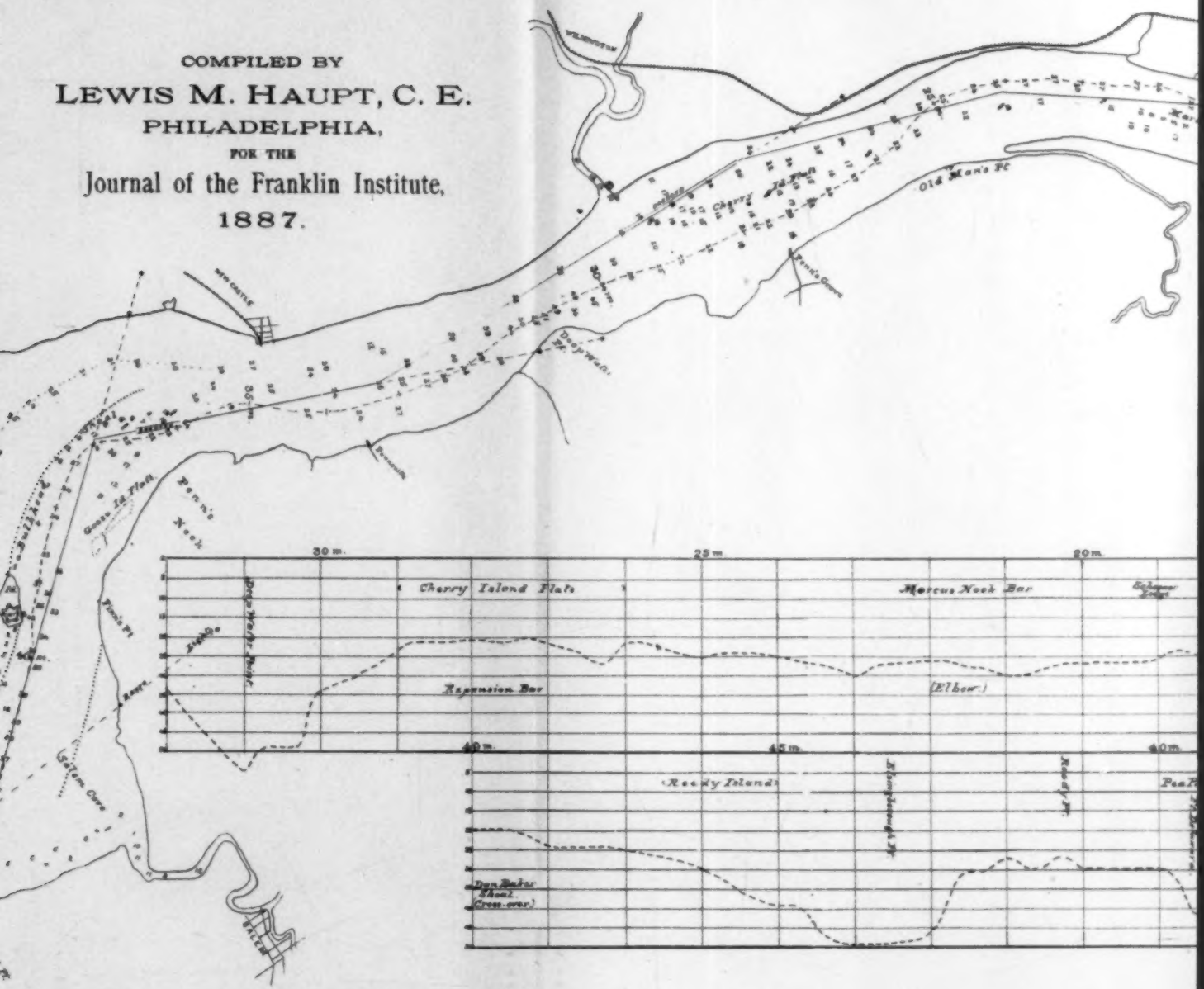
LEWIS M. HAUPT, C. E.

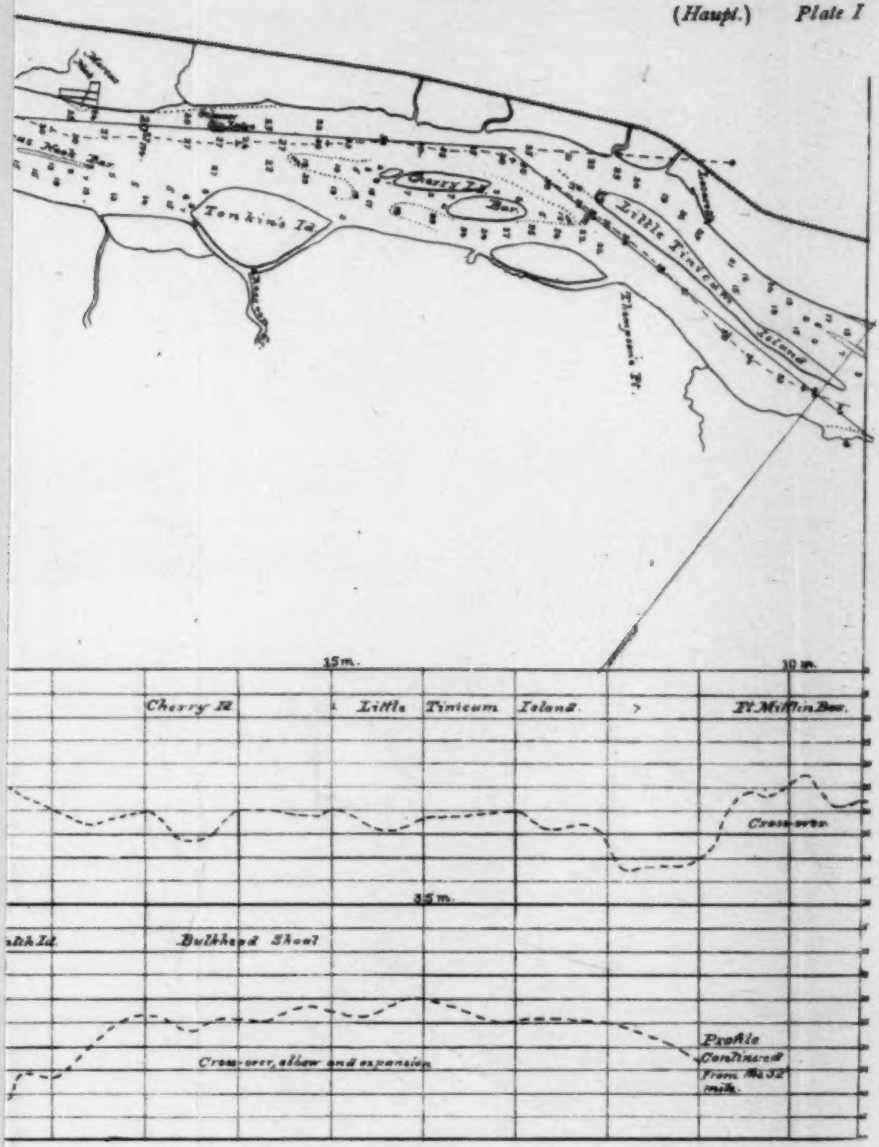
PHILADELPHIA,

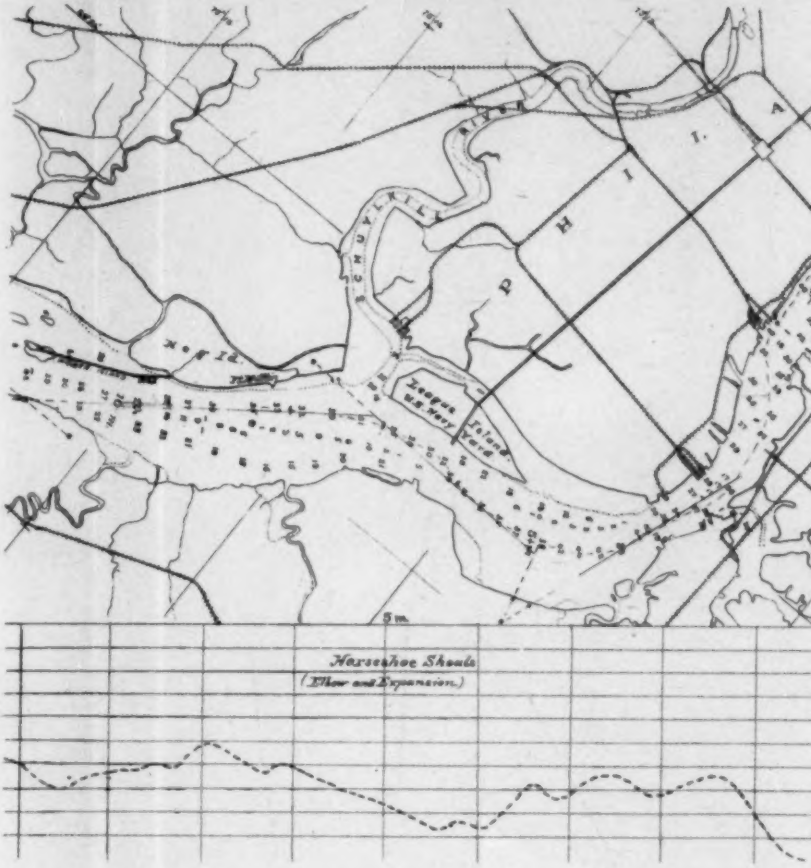
FOR THE

Journal of the Franklin Institute,

1887.




Tonkins Id.
Cherry Id.
Bar
Little Tinicum Island
Tinicum Pt.
15m.
10m.
Cherry Id.
Little Tinicum Island.
Ft. Mifflin Bar.
Cross-over.
35m.
Bulkhead Shoal
Cross-over, elbow and expansion.
Profile Continued From No. 32 mile.



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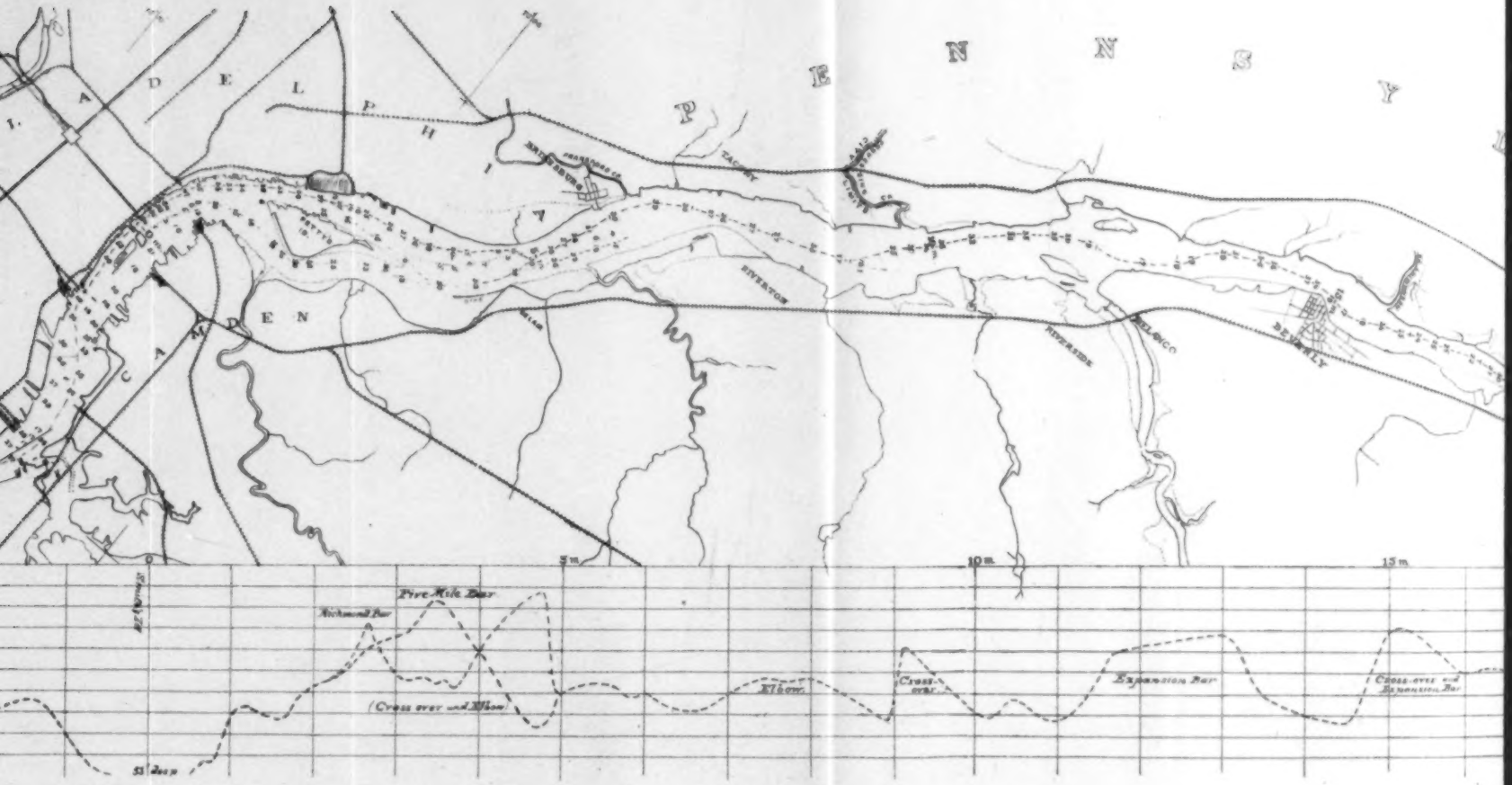

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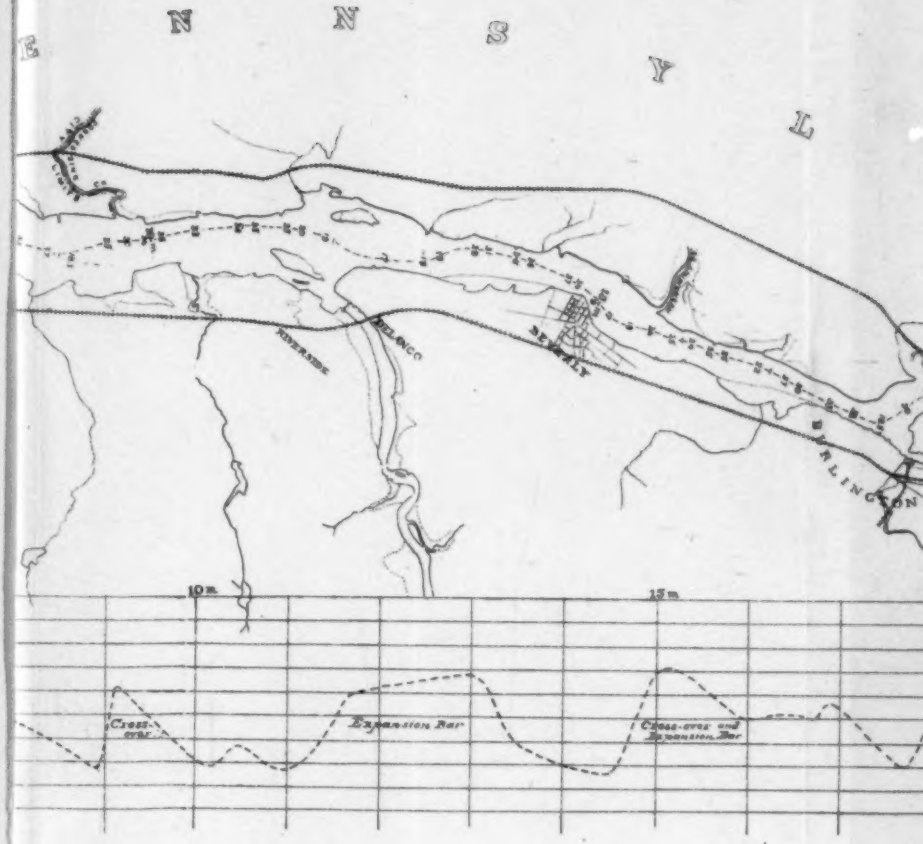

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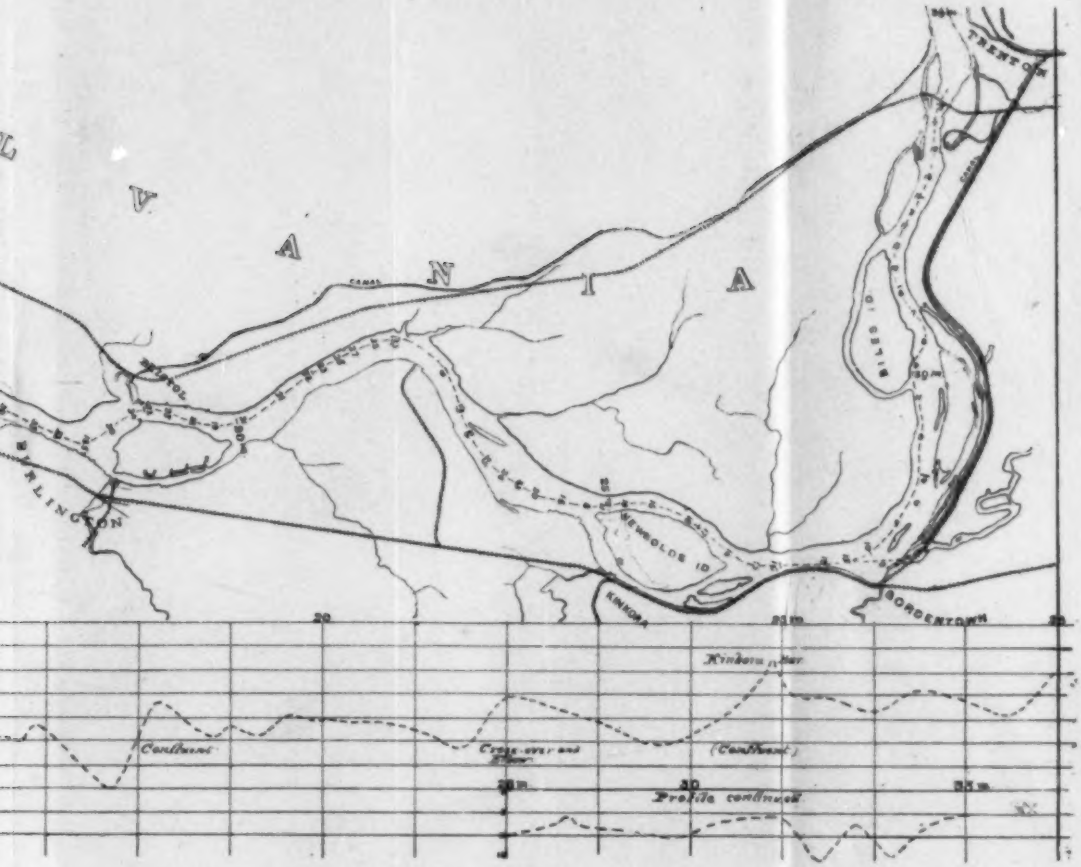

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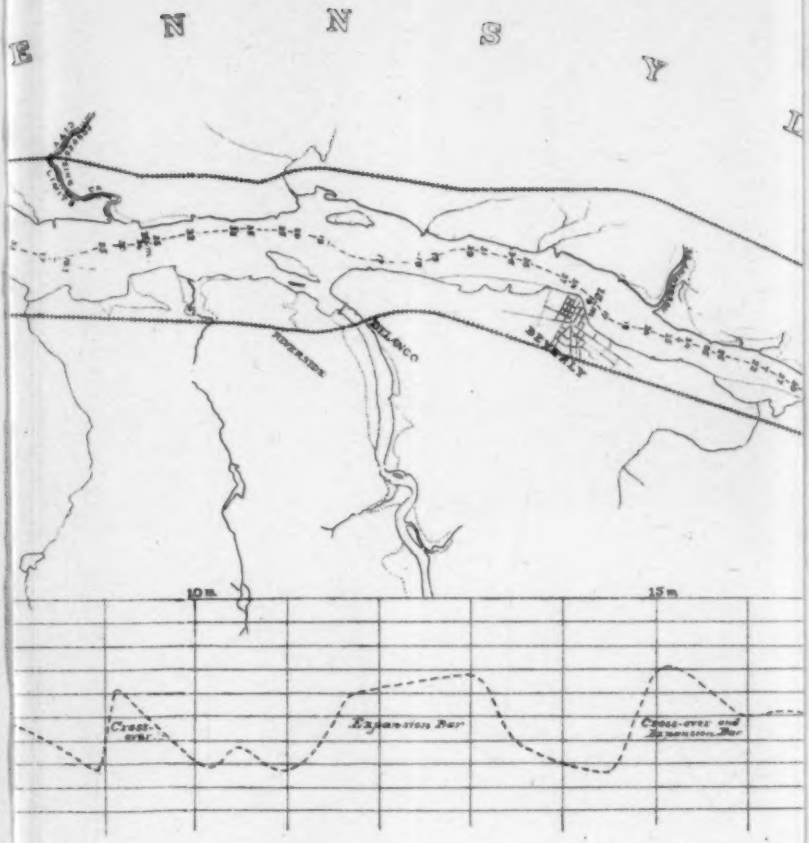

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LEWIS M. HAUPT, C. E.

PHILADELPHIA,

FOR THE

Journal of the Franklin Institute,

1887.

appeared, or had you sent me a marked copy of the paper in which you did publish, you would not have been kept waiting so long for my reply.

The burden of your objection appears to rest on my understanding of your letter of October 23d, in which certain remarks are made concerning the platinum contact and its opposing contact piece on the telephone membrane.

I quite agree with you that "such a nonsensical arrangement is against all common sense," and, indeed, as you will probably recall, I stated in my article in the January number of the JOURNAL: "It is difficult for us to believe that Dr. Stein could have so blundered as to experiment with an open-circuited apparatus." Nevertheless, your letter of the 23d of October is open to this interpretation, and I do not understand that in your open letter to me of May 25th, you deny the correctness of the translation of said October letter, since you say in your open letter: "The sentence in my letter to you of October 23d, was intended to mean that through the vibration of the membrane, while speaking or singing in the wood cube, the *platinum point* was lifted from the membrane and thus a transmission of sound through an interrupted circuit was made." You will, of course, recognize the fact that you can hardly hold me responsible for what you *intended* to say, but only for what you actually said.

I am quite willing, however, to accept your explanation as to what you intended to say with respect to the platinum contact and its position in relation to the telephone membrane, but would call your attention here to the unfortunate antithesis you made between this form of Reis instrument, and that other form of Reis instrument in which the platinum contact "rests directly on the membrane by gravity." If your meaning is that in the apparatus in controversy, the platinum contact *when not in use* rests on the membrane, but *when in use is thrown off from the membrane*, thus producing the breaks or interruptions in the circuit, which you allege prevent the transmission of articulate speech, then I am presumably correct in assuming that in the later form of Reis apparatus the platinum contact *not only rests on the membrane when not in use, but also when in use*, otherwise there would be no significance in your contrast of the two pieces of apparatus; or, as you say in you letter of October 23d: "By reason of this, there are here no interruptions of the current, but only fluctuations (undulations) in it, which is the desideratum for the production of articulate words or sentences." If you have been correctly translated here, you may perhaps understand my surprise at your failure to appreciate that just here lies the quintessence of the entire controversy. If Philip Reis did this, then he was the inventor of the articulating telephone, since he devised an apparatus that enabled articulate speech to throw electrical undulations on a circuit, which I suppose you will admit can transmit articulate speech.

It would appear, then, from your own testimony, that Reis was the true inventor and Bell merely the improver. The question is not, as you appear to think, who invented "the first useful apparatus for the practical far-speaking telephone," but who invented the articulating telephone? No one can deny that, taken as a whole, Mr. Bell's apparatus is better suited for

practical work than that of Mr. Reis, but Mr. Bell's apparatus constitutes, in the opinion of many well-known and reputable physicists in this country, a mere improvement on an apparatus already invented, and was not a new discovery or invention.

Since your open letter tacitly implies a wilful misunderstanding on my part of your letter of October 23d, I will here reproduce the original letter and the translation of the same, and leave the verdict concerning the matter to such of the scientific world as may be interested therein:

ELEKTROTECHNISCHE RUNDSCHAU,
Redaktion Kaiser Strasse 25, Frankfurt a. M.

FRANKFURT, A. M., den 23. Oktober, 1886.

HERRN PROFESSOR EDWIN J. HOUSTON, IN PHILADELPHIA.

SEHR GEEHRTER HERR!—Ich habe durchaus nichts dagegen einzuwenden, wenn Sie den Ihnen am 21. Juli d. J. geschriebenen Brief veröffentlichen.

Trotz Ihrer gefälligen Mittheilung, dass Sie selbst keinen Zweifel in die Angaben des Herrn Professor Paddock setzen, muss ich bei meiner Behauptung stehen bleiben, dass man mit dem Apparate, welchen ich Herrn Professor Thompson überlassen habe und den Herr Professor Thompson an die Overland Telephone Company weiter gegeben hat, nicht, wie mit den neueren Bell-Telephonen, Worte oder ganze Sätze, auf irgend eine Entfernung, auf die man nicht durch direkte Sprachvermittelung hören kann, zu übertragen vermag. Solches ist nur mit den Reis'schen Telephonen zweiter Form möglich (abgebildet in Thompson's Buch: *Philip Reis, Inventor of the Telephone*, Seite 86), weil man an diesen Apparaten die Membran beliebig spannen kann, und weil hier der Platinkontakt nicht, wie bei meinem, Herrn Professor Thompson überlassenen Apparate, etwas von der Membran absteht, sondern direkt nach dem Gesetze der Schwere auf der Membran ruht, mithin hier keine Stromunterbrechungen stattfinden, sondern nur Stromschwankungen, wie solches das Desiderium bei Hervorbringen von artikulirten Worten oder Sätzen ist.

Die kürzlich publicirte Beobachtung von Francis E. Nipher, dass man bei einer bestimmten Spannung der Membran mittelst des Reis'schen Telephons Worte übertragen könne, halte ich für vollkommen richtig und bin überzeugt, dass jedes Mal, wenn, wie vor 25 Jahren, Worte oder kleine Sätze mit dem Reis'schen Telephon zweiter Ordnung übertragen haben, die Membran richtig gespannt war; es war immer ein Zufall, wenn dies geschah, da Reis selbst in den Vorträgen über sein Telephon auf die richtige Spannung der Membran kein besonderes Gewicht gelegt hatte.

Wenn Sie auch diese Mittheilungen im JOURNAL DES FRANKLIN INSTITUTS publiciren wollen, habe ich nichts dagegen einzuwenden.

Ich bin mit vorzüglicher Hochachtung,

Ihr ergebenster DR. STEIN.

[*Translation.*]

ELEKTROTECHNISCHE RUNDSCHAU,
Editoral Office: Kaiser Strasse 25, Frankfurt a. M.

FRANKFURT A. M., October 23 1886.

TO PROFESSOR EDWIN J. HOUSTON, IN PHILADELPHIA.

DEAR SIR:—I have not the slightest objection to the publication of my letter to you, dated July 21, 1886.

Notwithstanding your statement, that you have no reason to doubt the accuracy of the declaration of Professor Paddock, I must stand by my assertion, that, with the apparatus which I gave to Professor Thompson, and which he subsequently gave to the Overland Telephone Company, it is not possible, as it is with the more recent Bell Telephone, to transmit words or whole sentences to any distance beyond that at which the spoken words may be heard directly. Such transmission is only possible with the Reis telephone of the second form (illustrated in Thompson's book: *Philip Reis, Inventor of the Telephone*, page 86,) for the reason that in this apparatus the membrane may be tightened to any extent, and also because in this, the platinum contact does not stand-off somewhat from the membrane, as in the apparatus which I gave to Professor Thompson, but rests directly upon the membrane by gravity. By reason of this, there are here no interruptions of the current, but only fluctuations (undulations) in it, which is the desideratum for the production of articulate words or sentences.

I consider the recently-published observation of Francis E. Nipher, that, by giving the membrane a certain tension, it is possible to transmit words with Reis's telephone, to be quite correct; and I am convinced that every time we succeeded, 25 years or more ago, in transmitting words or short sentences, with the second form of the Reis telephone, the membrane had just the right tension. It was always an accident, when this happened, for Reis himself, when lecturing on his telephone, attached no particular importance to the proper tension of the membrane.

Should you wish also to publish this communication, you are at liberty to do so. I am with high esteem, etc., DR. STEIN.

I note what you say as to the bored-block transmitter, etc., "Nevertheless, neither Philipp Reis himself nor I, *nor any other German experimenter*, (my italics) has ever been able to converse with a Reis bored-block transmitter and a Reis knitting-needle receiver, as is claimed to have been done by Mr. Paddock." I presume the italicized statement as above is intended merely as an expression of your own belief, since you can hardly speak with such positiveness for the very numerous experimenters of Germany.

As regards the statement made by me in the article in the January number of the JOURNAL OF THE FRANKLIN INSTITUTE, viz: "Although the author has not personally repeated the experiments of Mr. Paddock with the original apparatus of Reis, yet he is disposed to give full credence to the statements of Mr. Paddock, because he (the author) had, prior to the publication of Mr. Paddock's

letter, held an almost uninterrupted and quite intelligible conversation, continuing for some five or six minutes, in which questions and answers were given and received, by the use of a transmitter, which was an exact reproduction of the Reis bored-block transmitter, and employed the platinum contacts found on the Reis apparatus; and also because he does not see any essential structural differences between this form of transmitter and that in extensive commercial use to-day by the Bell Telephone Company."

Concerning the above, you say: "It is plain, assuming the correctness of the statements, that while using a Reis transmitter, you MUST have used a Bell Telephone RECEIVER. You cannot well venture to deny this fact, although you ignore it in your article." Permit me to suggest that this statement by you seems to me to prove conclusively that you have failed to appreciate the real question at controversy. If you will read the title of my paper of January, 1887, you will see that it is: "Can the Original Reis Telephone *transmit* Intelligible Articulate Speech." The entire question as a matter of invention is limited to the *transmission of speech*. I did use a Bell telephone receiver, but that has nothing to do with the question as to whether the apparatus, shown in *Figs. 1*, and *2*, of my article, and in *Figs. 1*, and *2*, of your open letter, are capable of *transmitting* articulate speech. The controversy is as to whether certain forms of Reis transmitters can transmit speech. You argue that they cannot, because you allege they produce interruptions or breaks in the circuit. I argue that they did, can, and will transmit speech. So far as this question is concerned, what matters it as to the particular form of receiver employed?

The following statement is made by you in reference to the tension of the membrane as described in Mr. Paddock's letter, viz.: "But more remarkable is the story of Mr. Paddock, which you, a scientific physicist, adopt, that he obtained the required tension of the membrane in the wood-cube telephone of Reis through the action of *sunlight*. What an imputation is involved in producing such scientific nonsense before the physicists of the whole world. Do not the two gentlemen know that every animal membrane is very hygroscopic, and that in speaking against such a membrane the moisture of the breath is absorbed, and the membrane must loose its tension, even though Mr. Paddock let the sun shine in his mouth while using the apparatus." The above is such a remarkable illustration of your apparent failure to understand the meaning of a plain statement, that I will rest satisfied with clearing myself before "the physicists of the whole world" by *simply quoting the only remarks* in Mr. Paddock's letter in which any reference to sunlight is made.

Mr. Paddock says on this point:—

"The requisite tension of the membrane I have found to be necessary as Dr. Stein remarks. But in the absence of any mechanical means, such as is furnished by the later forms of the Reis apparatus, I have obtained the desired tension of this membrane by exposing the instrument for a short time to a dry and warm current of air, or still better, to the direct rays of the sun, without detaching the membrane in any way from the wooden block to which it is secured. Under these conditions any degree of tension can be obtained

which is desired, and care only has to be exercised that this tension shall not be *too great!*"

I must take very decided exception to your charge of my suppressing facts—you say: "How is it that in your criticism of my communication you suppressed the fact that Mr. Paddock changed the Reis apparatus and did not experiment on the basis of the mode of the inventor, Ph. Reis." If Mr. Paddock made any such changes as you claim, or any changes at all, I was and still am entirely ignorant of the same, beyond what you state, since I have not at hand the report of the Overland case to which you refer. I will, therefore, leave it to Mr. Paddock to answer you in this regard, if he should think it necessary.

In a subsequent paragraph you say: "I will in your favor and to your honor believe, that you had no knowledge of *the changes which I made* on the original bored-block telephone, which went to the United States through the agency of Prof. Silvanus P. Thompson, of London." I note the necessity which has again arisen for an explanation on your part as to the correct meaning of the portion of your letter above, which I have italicized, and the very careful explanation you have given in the *Electrician and Electrical Engineer*, for September, 1887, in which you state that the above phrase, as translated for that paper, should read, "I will in your favor and to your honor believe, that you had no knowledge of the changes which *were made* (in America) on the original bored-block telephone, which went to the United States through Prof. Silvanus P. Thompson, of London."

If this is what you mean, then permit me to ask with which of your statements quoted below you wish to be credited, viz.: "How is it, that in your (my) criticism of my (your) communication you (I) suppressed the fact, that Mr. Paddock changed the Reis apparatus;" and, "I will in your favor and to your honor believe, that *you had no knowledge of the changes* which *were made* (in America) on the original bored-block telephone, etc."?

Quite on a par with the lack of courtesy displayed in the above, is your statement that: "The first principle of German science is *truth*." The slur you here attempt to cast on American science is not worthy of being answered.

In conclusion, permit me to say that I am quite willing to have the scientific world pass judgment between us, as to "the manner in which we use our scientific weapons."

EDWIN J. HOUSTON,
Prof. of Physics,
FRANKLIN INSTITUTE.

CENTRAL HIGH SCHOOL.

PYRO-MAGNETIC MOTORS AND GENERATORS OF ELECTRICITY.

In the very rapid growth and development of the appliances for the generation and utilization of electricity for practical purposes, the dynamo, considered as a commercial machine for converting different forms of energy, stands almost alone in the history of inventions in the rapidity in which it has been developed to practical perfection as far as efficiency of conversion is concerned, ninety-five and even ninety-seven per cent. efficiency from the belt to the available electric energy being now of common occurrence among the better class of dynamos. Inventors must therefore confine their attention to the improvements in mechanical details, and to the reduction in size and cost of the machine. Regarding the size of the dynamo, our knowledge of the principles involved shows us that there are practical limits, such as the limits to the magnetization which can be generated per square inch of cross-section of core, the limits to density of current in the wires of the machine, the limits to the speed of the moving parts, etc., all of which limits have been reached or nearly reached in the best forms of dynamos. It is safe therefore to say that improvements in dynamos will, in general, be confined to details and will not be of a nature to completely revolutionize the present form, considering it as a machine for converting mechanical into electrical energy.

The dynamo is, however, in most cases driven by a steam engine, which in turn requires a boiler, in order to obtain the energy from the coal, which is at present our chief and cheapest source of energy. The steam engine by itself has a tolerably high efficiency, if this efficiency be determined from the available energy at the pulley, and the difference in the energy of the steam as it enters and as it leaves the cylinder; but as the exhaust steam in most cases contains a very large amount of energy, and as the supply steam requires for its generation the inefficient boiler, the real commercial efficiency of both together is very low, being for small powers scarcely more than five to ten per cent., considering the energy in the coal and that which is actually obtainable from the engine. In the very best condensing engines and most approved boilers, and for

very large powers this may be as high as eighteen or perhaps even twenty per cent., but this high efficiency is obtainable only at a great prime cost which is in many cases prohibitory.

Furthermore, the first cost of the engine and boiler is, even for small electrical installations, a very large part of the total first cost of the plant, besides involving a large cost of attendance and maintenance, as compared with that required for the dynamos. The direction in which the attention of inventors is therefore led in order to decrease the cost of electrical energy, is not so much in the improvement of the dynamos, but to supplant the inefficient steam engine and boiler by a better device. It is evident that if such a device or machine could be made which, involving the generator of the electricity, costs as much as boiler, steam engine (including accessories) and dynamos together, which has the same total commercial efficiency, which requires as much attendance and cost of maintenance, and which involves the same indirect expenses for space, buildings, insurance, water, etc., it is evident that it would be on a par with the present system. If such a device or devices reduces any of these costs, whether directly or indirectly, or if it increases the efficiency, it is evidently superior; while if it far exceeds the present system in cheapness or efficiency, it will obviously supplant the steam engine for power purposes, by reconverting the electrical energy into power by means of electric motors, or by direct conversion of the energy of coal into power by direct magnetic or electric devices. As the first cost and cost of maintenance and attendance of the steam engine and boiler is very great, and the efficiency very low, the object to be accomplished by the electrician, namely, to devise a cheaper or more efficient apparatus, is not a difficult one, the difficulty being "how to do it" rather then "what is to be accomplished." One has only to consider the large coal and machine space in a large ocean steamer, to appreciate the great gain of an improved motive-power.

At the recent meeting of the American Association for the Advancement of Science, held in New York, Mr. Thomas A. Edison called the attention of the public to a very interesting and ingenious device, by means of which he has been able to convert the heat of coal or gas into electric currents by means of magnetism. The paper he prepared is reprinted, among other journals, in the *Electrical World*, Aug. 20, 1887, p. 105, and Aug. 27, 1887,

p. 111; *Electrician and Electrical Engineer*, September, p. 356; *Scientific American*, Aug. 27, 1887, p. 128; *Manufacturer and Builder*, September, 1887, pp. 194-210.

The general principle of this machine involves the following well-known laws. That a current of electricity is generated in a wire if it moves through a magnetic field across the axis of magnetism, or, in other words, if it cuts lines of magnetic force. This may be done by moving the wire across the lines of force, as in the ordinary dynamo, or by moving the magnets passed the wire, as in some alternating current machines, or by moving the lines of force across the wire by changing their position from one side of the wire to the other. This latter is the principle involved in the alternating current "transformers," or "converters," as explained in the JOURNAL OF THE FRANKLIN INSTITUTE, July, 1887, p. 76, in which therefore both the magnet and the coil are relatively fixed. This latter is also the method of the induction in the Edison pyro-magnetic generator. The other principle involved is based on the law that when iron is heated to a certain degree, it loses its magnetic qualities, or its power to concentrate lines of force in it. If, therefore, a core of iron wound with a coil of wire be placed lengthwise between the poles of a magnet, the lines of force will be concentrated in it, and if it is then heated, they will no longer have the tendency to pass through the core only, but some of them will pass out from the core where they may be considered to have been "confined," and pass directly between the poles of the magnet. In moving from the position in the core to that outside of the core, they must "cut" the coil of wire, and therefore generate a momentary current in it. When the iron is again cooled, these lines will pass from the outside of the coil back again to the core, thus cutting the coil again, and generating a current in the opposite direction. This will give an alternating current, which may be commuted into one of constant direction if desired by a suitable commutator.

The details of the machine have already been described and illustrated in the journals mentioned above, as well as in others, and it is therefore unnecessary to repeat the description here. It will suffice to state here that the machine consists in general of a core of soft iron made of sheet metal, having a thickness, we are

told, of ·002 of an inch,* and rolled so as to permit hot gases to pass between the sheets; this core is surrounded by a coil of wire, and while the core is in a strong magnetic field, it is alternately heated and cooled, thus inducing currents in the coil.

The regenerating principle of using the current generated by the machine to supply the magnets, has, we are informed, been applied to this machine, as well as the heat regenerative principle, that is the utilization of the waste heat to warm the air used in the combustion of the fuel, thus increasing the temperature of the heat. It is stated that such pyro-magnetic generators are beautifully self-regulating for constant potential.

A further study of the principles involved will show that there are practical limits to the development of such a generator, some of which have been very nearly, if not quite, reached in this machine. The chief one of these is the limit to the speed of cutting lines of force, and therefore a limit to the electro-motive force, or electrical pressure, which can be generated with a given field magnet. It is well known that it is the electro-motive force or electrical pressure, and not the current which is primarily generated by any electrical generator, the current being dependent on this electro-motive force, the size of the wire and the external resistance. This electro-motive force is proportional to two factors, first, to the amount of magnetism, or the number of lines of force, which is practically unlimited, as the field magnets may be made of any size; second, to the speed with which these lines are cut by the wire, which in this machine is dependent on the speed with which the magnetic qualities of the iron core may be destroyed and restored by the heat. This latter has a comparatively low limit in practice, 120 heatings per minute being, we are informed, the fastest rate at which these changes can take place. This means that the useful lines of force of the field magnet can be cut only 240 times a minute, while in the ordinary dynamo, having a speed say of 1,200 revolutions, the lines are cut 2,400 times a minute; from this alone it would follow that the amount of magnetism of a pyro-magnetic generator of this kind, neglecting all other factors, would have to be ten times as great as in a dynamo generating the same potential. Such

* The thickness of the paper of this JOURNAL is very nearly ·003 of an inch.

a generator is therefore allied to a dynamo having a very low speed, and must therefore be quite large as compared to an ordinary high speed dynamo for the same output. Other considerations will modify these proportions somewhat, but as Mr. Edison himself states, the machines of this kind must necessarily be quite large and heavy. Fortunately, however, magnetism is cheap, and the large size and heavy weight of a machine is not always a very objectionable quality; it is outweighed many times by the fact that such a machine is stated to require no more attendance than that required for an ordinary furnace for heating houses.

Another feature of these pyro-magnetic generators, and one which will no doubt present many serious difficulties, is that the iron cores which are to be heated and cooled so rapidly, must necessarily be made of very thin metal, and as it has to be heated to redness to destroy the magnetic qualities, it is evident that rapid oxidation and disintegration of the metal will take place, which will seriously affect the life of those parts of such a machine. This feature may, however, not be an insurmountable obstacle, and opens a sphere for inventive genius or for discovery.

It is evident that the source of the electrical energy generated is the heat of the fuel, and that it takes more heat to raise the temperature of a magnetized piece of iron to redness than a piece which is not magnetized, or stated in technical terms, the specific heat of magnetized iron is greater than that of unmagnetized. The difference is evidently that which may be converted into electrical energy. It is of course not necessary to heat and cool the iron through a greater range of temperature than is required to produce the magnetic change, which range it is said is not very great, and therefore it may ultimately be possible to limit the heating and cooling in such a way that the greater part of the heat actually consumed is in this difference in the specific heats, thus making the efficiency of conversion very high. This also opens a sphere for inventive genius. The difficulties, however, which are encountered here are analogous to those in the ordinary boiler, as the heated products of combustion pass off at a high temperature, thus lowering the efficiency of conversion very greatly.

Although it is difficult to make any predictions at a time, like the present, when inventions and discoveries are so numerous, yet we are probably safe in venturing to say that the great problem of

obtaining electrical energy directly from coal or other cheap sources of energy, will ultimately be accomplished in a different way than by means of such pyro-magnetic generators. Although this is a step in the right direction, it is by no means a complete solution of the problem. The chief alternative methods at present known to us are the thermopile and the battery. While the future of the former does not seem to be promising, the latter has already made considerable progress, chiefly in the form of batteries consuming heat or some cheap fuel, such as gas or carbon.

In the history of the development of the pyro-magnetic generator, we are pleased to be able to record another instance, in which the germ of a great invention or discovery was first brought before the public in the FRANKLIN INSTITUTE. The chief underlying principle of the pyro-magnetic generator of electricity is that of the pyro- or thermo-magnetic motor, which, it appears, was invented by Profs. E. J. Houston and Elihu Thomson, at that time professors in the High School of this city, and first described by them in the JOURNAL OF THE FRANKLIN INSTITUTE, for January, 1879, p. 39, as follows:

A CURIOUS THERMO-MAGNETIC MOTOR.

BY PROFS. EDWIN J. HOUSTON and ELIHU THOMSON.

During investigations by the authors, concerning the increase in the coercitive force of steel by changes of temperature, the following curious thermo-magnetic motor was devised. This motor, though devoid of practical value, will, no doubt, be of sufficient scientific interest to warrant a short description.

In *Fig. 1*, a disc or ring of thin steel, *D*, is mounted on an axis, so as to be quite free to move. The edges of the wheel are placed opposite the poles *N* and *S*, of a magnet. In this position the wheel, of course, becomes magnetized by induction.

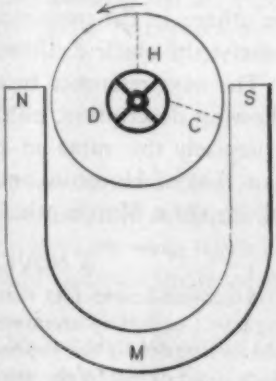

FIG. 1.

If now, any section of the wheel, as *H*, be sufficiently heated, the disc will move in the direction shown by the arrow. The cause of this motion is as follows: The section *H*, when heated, has its coercitive force thereby increased, and being less powerfully magnetized by the induction of the pole *S*, than the portion *C*, immediately adjacent to it, the attraction exerted by the pole *S* on the latter portion is thereby sufficient to cause a movement

of the disc in the direction shown by the arrow. If a constant source of heat be placed at *H*, a slow rotation in the direction shown is maintained.

To ensure success, the disc must be sufficiently thin to prevent its acquiring a uniform temperature. If the source of heat be at the same time applied at diametrically opposite portions of the disc, as at *H* and *D*, adjacent to the poles, the same effect will be produced. Since the amount of heat expended in producing motion of the disc is so enormous when compared with the force developed, it will be readily understood that this motor is of no value as such, but must be regarded as an interesting example of the inconvertibility of force.

Expressed in more modern terms, the explanation of the rotation of the disc is that the heating of the two diametrically opposite parts, thus demagnetizing them, acts as though these parts of the disc were cut off, leaving an inclined piece of magnetic iron, which, therefore, receives a more or less tangential pull by the shifted lines of force to bring it into the direction of the axis of magnetization of the field.

It will be noticed that in both the motor and the generator the general principle is the same, namely, that the demagnetization of iron by heat is used to change the position of the lines of force; in the motor, this change of position is made use of to turn the iron armature on its axis, and in the generator the change of position of the lines is made use of to induce a current by causing the lines to "cut" the wires of a coil. The difference between the two is, therefore, not analogous to the difference between the ordinary electric motor and dynamo, of which one is the exact reverse of the other; in the pyro-magnetic generator there is a new element, namely, the electric current, which is entirely absent in the motor.

The next reference to a pyro-magnetic motor appears to be the following description, published five years later, of a motor which is precisely the same in principle, though evidently less efficient than that of Houston and Thomson. It is taken from *Science*, vol. iii, 1884, March 7th, No. 57, p. 274.

A NOVEL MAGNETIC ENGINE.

It is a well-known fact that iron, when heated to a red heat, ceases to be magnetic; so that an armature, after being heated to redness, may be removed from its magnet by the expenditure of only a small fraction of the energy which is developed by the attraction of the same armature when it has cooled.

Manifestly, this fact might be employed in the construction of a motor, which, while of no practical value, is of theoretical interest, in which a per-

manent magnet should act as the direct motive force. This has been done in the following manner: In *Fig. 2*, *a*, *b*, *c* represents a ring thirteen centimetres in diameter, and supported horizontally upon radial arms and an axis of some non-magnetic metal. This ring is made of one or more turns of iron wire of about a millimetre diameter. *N S* is either a permanent or an electro-magnet. The axis is furnished with a driving pulley, cord and weight, as shown in the figure.

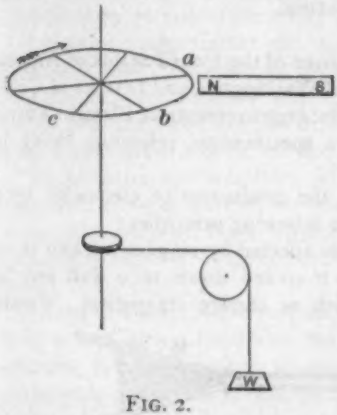

FIG. 2.

That part of the ring which lies between *a* and *c* is heated to bright redness by means of two or three Bunsen burners. The magnet then exerts a preponderating attraction upon the farther or cool side of the ring, and the latter revolves as indicated by the arrow. As fast as the ring enters the space *a*, *b*, *c*, it becomes red-hot and non-magnetic, and a lack of equilibrium is thus maintained, which results in a continuous rotation.

The motion is necessarily quite slow on account of the considerable time required to heat the iron ring. In the actual experiment, moreover, considerable difficulty was experienced from the distortion which the ring underwent when softened by the heat, in consequence of which the speed of rotation became very irregular. With a permanent steel magnet, a speed of about one revolution in two minutes was obtained; and with a powerful electro-magnet, a weight of six grams was raised fifty centimetres in six minutes, and in a second experiment, the ring having become quite distorted, ninety centimetres in thirty minutes.

Of course, the source of energy is the Bunsen burners; and the experiment leads at once to the fact that the specific heat of magnetized iron is greater than that of unmagnetized.

CHAS. K. MCGEE.

University of Michigan, Ann Arbor, February 19, 1884.

It will be noticed that this is not only no improvement of the earlier form, but as the field is not a closed one, it is evidently not as effective nor as efficient. It is nevertheless a very ingenious invention and appears to have been made independently of the earlier form.

Next in the order of date appears to be the invention of a pyro-magnetic generator by Emile Berliner, and called by him an "electric furnace generator." The following is a copy of his application for a patent, filed June 18, 1885.

ELECTRIC FURNACE GENERATOR.

[*Filed June 18, 1885.*]

SPECIFICATION.

To all whom it may concern:

Be it known that I, Emile Berliner, citizen of the United States of America, residing at Washington, in the County of Washington, and District of Columbia, have invented certain new and useful improvements in Electric Furnace Generators, of which the following is a specification, reference being had therein to the accompanying drawing.

The invention has for its purpose the production of electricity by the assistance of heat, and it is based on the following principles:

Iron, when heated to bright red, is not affected by magnetism, and in turn does not react upon that force; but if cooled down to a dull red heat it instantly regains the ability to absorb or engage magnetism. Further-

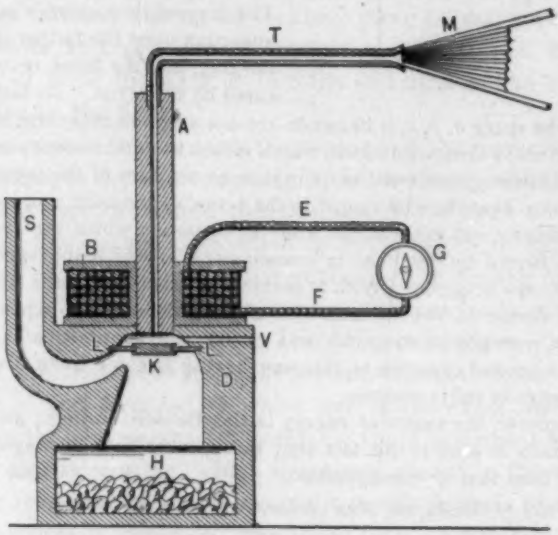

FIG. 3.

more, if a magnet is capable of holding suspended a mass of iron, *i. e.*, an iron armature weighing not more than, say twenty pounds, it will also be capable of holding suspended on it a mass of brass, or other non-magnetic material weighing, say fifteen pounds, by means of an iron armature weighing only a fraction of an ounce.

This shows that in order to engage, say three-quarters of the attractive capacity of a magnet, a very small portion of the equivalent weight of iron is required to do this. It is also well known that the greater the amount of displacement of the magnetic field in a magneto-electric generator, the greater is the current produced in the conductor of said generator.

If now I take a magnet and provide it with a coil around its pole or poles, and place before this magnet and in proximity to the coil a piece of iron

heated to bright red, nothing will occur to disturb the magnetic field, but the instant the iron cools down to a dull red the magnetism becomes excited, and a momentary current of electricity is produced in the coil.

I may go a step further and have a series of such magnet coils and iron armatures, and by connecting the coils into the same circuit and cooling the armatures in rotation, one after the other, a number of electrical impulses will be produced which, when they follow one another rapidly, will approximate a continuous electric current.

These being the underlying principles of my invention, which, of course, is capable of being worked out into different devices for the accomplishment of the same purpose, I will confine myself in this specification to a simple apparatus, capable of demonstrating the underlying principles heretofore stated. (*See Fig. 3*).

In the drawing, *A* is a magnet, having a tubular hole through its centre. *B* is a coil of insulated wire, the insulating material being fire-proof, like asbestos, cement or other fire-proof substance. *D* is a brick furnace provided with a fire-box *H* and chimney *S*. *K* is a plate or disc of iron, set inside a brass ring *L*, which in turn is so imbedded in the upper part of the furnace that the flames cannot strike above it, but will heat it only from below. The terminals of the coil, which are *E* and *F*, are closed through the galvanometer or other electrical apparatus *G*. A tube *T* is inserted into the top of the magnet and is provided with and connected to a pair of bellows *M*.

In order to produce electricity, a fire is started in the box *H*; the heat on its way to the chimney must then impinge against the iron armature *K*, which under the continuous influence of the heat, will soon be rendered bright red, when it will have lost its power to engage the magnet *A*.

If now the bellows be compressed, a current of cooler air will be forced through tubes *T* and *S*, against the plate or disc *K*, and out through the vent holes *V*. As soon, however, as the air strikes the plate *K*, it will cool it sufficiently to reduce the bright red to a dull red, and instantly the magnetic influence will be re-established, and a corresponding change in the magnetic field will be accompanied by an electric impulse in the coil *B*. If now the current of cooled air be discontinued or averted, the plate will again resume the bright red, and a current in the opposite direction, but of less intensity, will occur in the coil *B*.

It is evident that a working up and down of the bellows at a slow enough rate will alternately change the bright red to a dull red and the reverse, and the consequence will be a series of electrical impulses in the coil *B*, which may then operate the electrical apparatus *G*.

It will be observed, since the depression of the bellows requires comparatively little force, that the principal acting force is the heat, which suspends the magnetic influence between the magnet and armature, while a little draft of compressed cooler air re-establishes this influence suddenly. The current thereby produced might be utilized to charge another coil surrounding the magnet and re-enforce the magnetic field; and in that case the magnet might be substituted by a tubular core of iron; the bellows might be dispensed with, and a constant source of compressed air might be employed, regulated by

suitable mechanism to supply the air puffs to be directed against armature *A*; or even pieces of cold metal might be made to approach the armature at intervals, and cool it by contact with the same; or by absorption and radiation; or a series of coils and magnets might be placed toward one larger armature disc forming a common armature, heated by one furnace.

All these ideas can be brought to bear on the subject whenever time offers itself to experiment, which is the most effective modus. For the present, I claim:

The combination with the magnetic field and a conductor situated therein, of a piece of iron which is alternately heated and cooled, thereby producing electricity, substantially as described.

In testimony whereof, I have affixed my signature in the presence of two witnesses.

EMILE BERLINER.

CHARLES W. HANDY,
MYER COHEN, } Witnesses.

It will be noticed that this appears to be the first suggestion to use this principle to generate or induce an electric current, and, therefore, this ante-dates the publication of the description of Edison's invention of practically the same thing, by over two years. While Edison's form of the generator is unquestionably a very great improvement of this form, being more practical, effective and efficient, it involves no new principle, but differs only in details, which, however, are evidently very important ones, and which add to Mr. Edison's well-earned fame for his ability to reduce mere suggestions or laboratory experiments to practical devices, in which form they may be of use to the general public.*

CARL HERING.

NOTE.—Since writing the above, my attention has been called to a communication by Wm. B. Cooper, of Philadelphia, to the *Electrical Review*, New York, September 24, 1887, in which he states that he devised a motor of this kind in 1884–85, which he brought before the FRANKLIN INSTITUTE at that time. He also suggested the idea of generating electricity by this principle. He was very much discouraged, however, by the fact that the iron oxidized very rapidly. He also refers to an article by D. Gore, *Philosophical Magazine*, vol. xl, 1870, p. 173, in which is described an electrical *generator* based on this principle, and which, therefore, anticipates the idea of Berliner and Edison. In Gore's apparatus there was a coil at each end of a bar of iron, a battery current was made to flow through one, and the other was connected to a galvanometer; on heating and cooling the bar in the middle a current was indicated in the galvanometer. C. H.

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*The JOURNAL is indebted to the *Electrical World* for the use of the engravings used in this article.—THE COMMITTEE.

On FLINT'S INVESTIGATION of the NICARAGUAN WOODS.

By R. H. Thurston, Director of the Sibley College of Cornell University.

[*Presented to the American Association for the Advancement of Science, New York Meeting, August, 1887.*]

Preliminary Remarks. By R. H. Thurston.—It had long been a conviction of the writer that the tropical and semi-tropical countries of America possess a large number of valuable timber trees of which nothing is known by our engineers or builders, but which, for some of the more important purposes, as well as for ornamental and exceptional constructions, may have extraordinary value. As the process of stripping our own land of timber goes on, and as our pines and finer grades of timber trees become gradually more and more difficult and costly of procurement, the necessity will become more and more pressing of going into the more heavily forested countries nearer the equator for our supplies of lumber. It is thus becoming continually more important that we learn something of the resources of such countries, and especially of the useful qualities of the woods available for building purposes. A knowledge of the extraordinary strength, and of the other valuable properties of some of these timbers, will unquestionably, in time, lead to the opening of our markets to them, and to a trade that may prove to be of inestimable advantage to both purchaser and vendor. A few years more will see the great forests of the Northwest stripped of their best timber, and the supply will then be mainly drawn from the South and the Pacific Coast; but the enormous rate of growth of the country in population, and still more in manufactures, will sweep those districts clean at a rapidly increasing rate of destruction, and it will be found, probably much sooner than is now generally imagined, that we must look elsewhere for the enormous supplies demanded by our markets. The growth of this demand is a geometrical one.

That most remarkable of recent works on economical subjects, that romance of statistics, *Triumphant Democracy*, gives some striking facts abstracted from the last census. Mr. Carnegie finds

that our lumber trade has quadrupled within the generation, the business now employing about 150,000 men, and producing nearly $250,000,000 worth of lumber. About $40,000,000 is invested in this trade in Michigan alone, and the three states, Michigan, Minnesota and Wisconsin cut, in the year 1880, over 7,000,000,000 feet of timber, in the form of marketable lumber, besides millions of feet in the shape of railroad ties and other minor products. It is estimated that the pine forests of the northwest will be gone in about twenty or twenty-five years; but the southern forests are of much greater extent. It is not certain that we shall very soon be entirely deprived of the light and comparatively soft growing woods; but their extinction would seem to be but a matter of time, and, as the lives of nations are counted, not a long time.

Mr. Jessup has collected for the New York Museum of Natural History some 400 varieties of North American woods, including very many which are of very great value for constructive purposes; some of these, as the sycamore, have not been as yet much used, but are now being found to have peculiar value for special purposes. The consumption of these hitherto neglected timbers will continually and rapidly increase. Others, as the live oak of our Gulf States, have been used exclusively for special purposes, as in ship-building, and have, by the progress of improvement in the art, been thrown out of use, to come in again at some later time in a way as yet unforeseen. The soft woods are those which, from their soundness and especially from the ease with which they can be worked, are in greatest demand, and, fortunately, they are those which have hitherto been most plentiful and cheap in our markets; but they are gradually becoming less accessible and more difficult of procurement; their cost is thus threatening to become seriously increased, and we are likely to be compelled to find ways of substituting the hard woods for the soft in our constructions. A century ago, oak was the most common of building timbers in the older countries of the world; it seems now possible that it, and the other hard woods, may, in time, again come into general use; but, if so, we must, after a time, go into the southern and neighboring states for such woods. Once we are brought to the use of such hard woods again, we shall, perforce, be brought to the construction of buildings capable of withstanding the teeth of time as effectively as did those of our ancestors of the middle ages.

We are to-day sending out into the markets of the world, annually, something like $30,000,000 worth, probably, of wood, in the form of manufactured articles mainly, particularly as furniture, and the time is coming when we shall supply a very large part of the world with its timber and manufactured wood products; but this will only hasten the day when we must look to the West Indies and to Central and Western America, perhaps to South America, for our own supplies

It was considerations such as have been above outlined that led the writer, some years ago, to endeavor to secure such data relative to the useful qualities of the tropical and semi-tropical woods as would, in the course of time, prove useful to our own people as well as to the citizens of those neighboring countries to which we shall be likely to first look for our supplies of the heavier sorts of timber; for it will be seen that nearly all of the semi-tropical and tropical woods are of the hardier varieties and are distinguished rather by their hardness and strength than by lightness and ease of working—the peculiar qualities of the varieties of the coniferæ from which we obtain the greater part of our timber to-day. The first attempt to investigate these hard woods of the warmer latitudes in a systematic and satisfactory manner was probably that undertaken some ten or fifteen years ago by French engineers and naturalists studying the trees of New Caledonia. Later investigations of a similar character have been made, usually since the work directed by the writer about to be referred to as initiating his own researches, by British authorities, in India and in the Australasian colonies of Great Britain. The first systematic study of these classes of woods in America, so far as the writer has observed, was made at the suggestion and request of the writer by Mr. E. D. Estrada and published in Van Nostrand's *Magazine* for November and December, 1883. Recently, another investigation has been undertaken in the Mechanical Laboratory of the Sibley College, Cornell University, by Mr. Rufus Flint, the results of which will here be presented. Mr. Flint, although by descent on the father's side an American, is a native of Nicaragua, and, until coming into the United States to obtain his education, has been a resident of that country. Through his relatives and friends and assisted by the liberality of the Government, which allows such material to enter duty free, Mr. Flint has been able to secure a fine collection

of the woods of Nicaragua, and thus to enter upon a research as important in its bearing upon the business interests of his own country and of the United States as that conducted by Mr. Estrada.

Examining the data thus secured by these investigators, we find that the tropical woods are distinguished by their extraordinary strength, elasticity, beauty of grain and durability. The few already known to us, such as mahogany, rosewood and some of the cedars, may be taken as illustrations of the several principal classes of timbers to be found in the forests of Central America and the Islands of the Caribbean Sea. These woods are all coming into demand very rapidly already, for house decoration, and in the construction of the finer grades of furniture, and an examination of the magnificent collection gathered at New York, by Mr. Jessup, will reveal the fact that we have but begun to make application of the enormous variety of woods which are readily obtainable and available for such purposes. These statements will be seen to be true of the woods of Central America here to be described, as well as of the Cuban woods already reported upon. In both cases, but a few of an immense number of woods have been taken for investigation; but these selected samples may be taken as illustrative of the whole product of this vast arboretum. The tropical trees attain enormous sizes, are extraordinarily solid, close and firm of grain, excel in the beauty and variety of their coloring, in fineness of texture, and especially in their wonderful durability, whether exposed to the corroding influence of the atmosphere, to the action of heat and moisture, or to the attacks of insects. Ironwood and lignum vitæ exemplify the first of these characteristics; mahogany, rosewood, tulipwood, and others, illustrate their beautiful color and grain; and the live oak and teak are good examples illustrating their power of resisting the action of oxygen and the attacks of the teredo and of the limnoria.

The investigations of the Central American woods were made in the several testing machines and the workshops of the Sibley College, and the results were reported to the writer in a paper presented in June last, the substance of which is here given. The report is so well written and so complete that it has been thought best to give the whole in the words of the observer. The figures have been very carefully checked, and are believed to be perfectly

reliable throughout. The machines used had been standardized and were known to be practically exact, and it is thought that the data thus obtained, as here given, may be of real value to the profession, as well as to the two countries most nearly interested in the results of the research. The native nomenclature is given throughout. It was found difficult to obtain the botanical names of all these woods, and, in many cases, those obtained were subject to some question in consequence of the fact that the botanists seem to have had comparatively few opportunities of study of these woods; but the introduction of the timbers of these regions into our own markets will undoubtedly lead to the adoption of the nomenclature obtained in their homes, and no inconvenience will arise, it is thought, from the omission of the technical names.

The examination of the Cuban woods, to which reference has been made, showed moduli of elasticity as deduced from the experiments on transverse stress and strain, varying from 1,500,000 to 2,500,000, British measure, the great majority of the dozen and a-half varieties studied ranging above 2,000,000, or equalling the stiffness of the Indian teak, and exceeding that of any known variety of our native timber, with the exception of an occasional sample of the strongest and stiffest of the choicest of Southern long-leaved, yellow pine. The figures for the best of the Cuban woods are above those of any known North American woods, exceeding their best figures by fifty per cent., nearly. Three-fourths of them are stiffer than the best teak. The moduli of rupture by transverse stress vary between 15,000 and 20,000 pounds per square inch, as a rule, in but one case falling to 8,000, and in several exceeding 20,000, the average being not far from 18,000. The densities average above that of water, and many samples exceed that unit by some twenty per cent. Quite a number of these woods have just the qualities which distinguish yellow pine of the finer grades; for example, Baria (*Cordia gerascanthoides*) and Caobilla (*Crotos lucidam*), as representing the lighter varieties, and Majagua (*Paritium elatum*), an even lighter and stronger wood; Dagame (*Colycophyllum candidissimum*), one of the most common of West Indian woods, weighing but fifty-six pounds per cubic foot, and having a modulus of rupture of 16,000 pounds.

Sabicu (*Mimosa adorantissima*) has just the weight of water, or a trifle less, and, with a modulus of elasticity of about 2,400,000,

exhibits a modulus of rupture exceeding 20,000. A dozen of these varieties are higher in rank than the best building material found in our native forests.

The Central American woods, growing on a more widely distributed area, in a soil of less uniform character and in a greater variety of climate, are naturally of more widely differing character than those of Cuba. The high and dry atmosphere and more innutritious soil of the interior, and the rich bottom lands of the swampy regions of the coast, with every intermediate condition of soil, climate and exposure, produce timber of soft as well as hard varieties, of less as well as of greater strength or elasticity, and thus yield to the market a larger assortment of useful woods than could any insular district. The moduli of rupture, as determined by Mr. Flint, vary from 7,000 to nearly 30,000, and the moduli of elasticity from about 600,000 to about 2,500,000, usually approximating 2,000,000, the modulus of rupture commonly falling at about 22,000.

INTRODUCTION BY RUFUS FLINT, M.E.

The woods of Nicaragua, grown under the sunny sky of the Torrid Zone, and in the mountains, valleys and on the sandy shores of the Atlantic and Pacific Oceans, are many in number and of widely different character in nature, strength and color. Unrestricted in their growth, in the exuberant and wild forests and woods of the country they attain enormous sizes, and exhibit great strength and solidity.

As a general rule, they are of delicate hues and beautiful colors, exhibit extreme fineness of grain and have marked peculiarities in texture and general appearance.

The investigation of their strength and natural properties is a matter of great interest. With the facilities offered in the Mechanical Laboratory of Sibley College for complete investigation of the materials of construction, I have thought it advisable to conduct such an investigation of a few of the Nicaraguan woods so as to make known the characteristics, not only of those that have found their way into the markets of this country and of Europe, mainly because of their worth as dye woods or for ornament, but also some others, perhaps of better if not equally prized properties, which have yet remained unknown in the industries.

In undertaking this investigation, I hope to find results which may prove of value and interest to the artisans of my native land, and also aid in developing, to a certain extent, the commerce and industries of Nicaragua, by making some of its natural products known in the United States and Europe.

I have restricted myself to the study of those woods which are most used in engineering construction and decoration, leaving out the dye and other woods, which, perhaps, may be of equal interest and value, there being quite as many unknown, or at least unused, valuable woods and plants of this latter kind.

I was encouraged from the start by Prof. Thurston, who very kindly wrote to the Government of Nicaragua, asking for a collection of the most important woods of the country, expecting that its officials would take, or at least show, some interest, and thus secure a good collection of the woods. But unfortunately we were in this disappointed. It was by my father's interest, kindness and persistence, and through my friend Miguel Ugarte's active and courteous help, that I was supplied with as good a collection as could be obtained in the short time allowed to collect them. Steps were taken to get the woods, seasoned and sound, from persons engaged in working them, but they failed to obtain them. It is for this reason that the woods tested have not been entirely satisfactory, as they were cut green, and the men could not in most cases fell large trees to get the heart or the best of the wood; as a consequence, they checked on the way, and many of them were found to be knotty. The woods were collected in one month, within a circuit of three leagues, on the hills about Belen in the agricultural and chocolate-raising "Departmento," of Rivas, between Lake Nicaragua and the Pacific Ocean. Some few, obtained from a carpenter, are seasoned. My collection of fifty different varieties represent about half the number of the useful woods of the country.

The terms used may be thus defined: The modulus of rupture for tension is the force necessary to pull asunder a bar whose section is one square inch, when acting in the direction of the axis of the bar.

The modulus of rupture for compression is the pressure necessary to crush a piece of any material whose section is unity and whose length does not exceed about five times its diameter.

The modulus of rupture for transverse stress is the stress at the instant of rupture upon a unit of the section which is most remote from the neutral axis on the side which first ruptures.

The modulus of elasticity is a value which expresses the relation between the extension, compression, or other deformation of a bar, and the force which produces the deformation.

Resilience is a measure of the capacity of a material to resist shock, and its value is equal to the amount of energy expended, or the "work" performed in producing distortion or rupture.

GENERAL DESCRIPTION OF THE WOODS.

(1.) *Carbon.*—Extraordinarily solid, equalled only by the Piedra and the Quiebra-hacha. Is almost imperishable when used for posts, and is supposed to be very good for railroad ties. The tree attains a height of 30 feet, and measures 12 inches in diameter. Is common in most of the wooded districts. The wood is of a very fine grain, with peculiar dark streaks; very much like the mahogany in appearance and in color, but heavier and much handsomer. Is easy of working, and turns very smoothly.

(2.) *Cedro* (Cedar.)—The wood, on account of its peculiar properties, has found a place in all the markets abroad. In Nicaragua, it is found abundantly, and attains enormous sizes. Is used extensively for furniture, frames, book cases, etc. It is even used by the Indians for boats, which they work out entire from the trunk of the tree.

(3.) *Chaperno.*—Dark red color, turns and planes very smoothly. It has a fine grain and great strength and is susceptible of high polish. It is used extensively for cross pieces of drawers and tables. Is extremely durable. There are two varieties of this wood, black and white, as they are called respectively. The tree attains a height of forty feet.

(4.) *Chiquirin.*—Dark yellowish wood with a strong cedar smell. Is heavy, fine grained and planes smoothly. The tree attains a height of thirty feet, and one foot in diameter. It has various uses, is durable, and having odor is probably not subject to attacks by insects.

(5.) *Cortez.*—Extremely heavy and very fine-grained, of a very dark yellowish color. When broken in splinters, it gives off a fine yellow powder, which has similar properties to litmus; it turns

bright red when mixed with soap water. It is a large tree like the Nacascolo. It is used in cabinet work, for framing, etc. The only place in which I can remember to have seen it growing is on a rocky hill at the foot of the volcano Mombacho, near the shore of Lake Nicaragua. The hill is covered with these trees, which, in the beginning of every spring, are a beautiful sight, being covered with yellow flowers.

(6.) *Granadillo-negro.*—Wood very much esteemed for interior decoration, on account of its handsome dark color, fineness of grain and ease of working. The tree attains a height of thirty feet, and is found on the shores of the rivers which flow into the eastern side of Lake Nicaragua.

(7.) *Gauchipilin.*—Fine grained wood of a light yellowish color, heavy and tough. The tree attains a height of 30 or 40 feet, and has a diameter of 15 inches. It is irregularly branched. Much used by the artisans for durable work, as it resists moisture for years. It is also used for telegraph poles and railroad ties. Is abundant all over the country.

(8.) *Guapinol.*—The tree is nearly as large as the Jenisero, and its branches large but more erect. The wood is of a light mahogany color, long grained, but very compact, heavy and tough. Is used almost exclusively for cylinders of sugar cane mills, while the teeth moving them are made of guachipilin, guayacan or other similar wood.

(9.) *Guayabo de Monte.*—Attains a height of sixty feet, is of irregular diameter, and seldom over two feet above the lateral roots, acting as braces, which support the trunk. It has a fine grain and is very tenacious. The test made probably does not show full strength, as it was an inferior sample. It is used for small masts and the weather streaks of boats. According to Mr. D. L. Murray, who preferred it above all others for launch guards, it resists wear and tear better than any other wood.

(10.) *Guiliguiste.*—A wood unknown to commerce. Has a light brown color in the heart, is fine and fibrous of grain. It ran above the average in compression. It is not as durable as the other hard woods, but from its beautiful grain and color, and from its ease of working, it would seem that it should be used for interior house work. The tree is small, growing only about 30 feet high, with a diameter from 15 to 18 inches.

(11.) *Jenisero.*—One of the most useful trees, and one of the largest in the country. Attains a height of 90 feet, with 7 in diameter, and its large branches cover a space of over 100 feet in diameter. In Nagarote, a town in the Departmento de Leon, at the junction of one of its streets with the large road from the western departmentos, there is a Jenisero whose branches cover a circumference of 348 feet (about 9,498 feet area); it is 90 feet high, and has a circumference of 21 feet at 4 feet from the ground, according to Senor F. Guerreo Baster.

The wood has a light to dark color, and a peculiar grain; it is open and wide in the annual rings, but very compact between. It is used for cart wheels, lasting for years without tires on clay soil. Used also by the carpenters in various ways. Its fruit is eaten by the cattle, and is used to sour the milk. It is fairly well distributed over the country.

(12.) *Jicaro-Sacaguacal.*—Attains a height of 20 feet, and a diameter from 10 to 12 inches. Common on marshy land. It is of a nearly white color and very tough, used in saddlery and for boat-knees. Resists moisture, and is durable in salt water. The shells of its fruits, after being worked, are used by the natives for drinking vessels. They carve them very beautifully and artistically.

(13) *Laurel.*—Dark color, light, strong and elastic wood and very easy of working. There are two varieties, male and female, as they are popularly called. Used mostly in frames for cots, and for work where elasticity is required. The dark kind is preferable. Both have a spicy smell. The tree attains a height of 40 feet, and a diameter from 8 to 12 inches, seldom over 8.

(14.) *Lligualtil.*—This is one of the trees having many peculiar natural properties. Its fruits have a rich fragrance and flavor, and when green give out a coloring substance. From its bark a bluish and sometimes a purple substance is obtained, and from its sap thirty per cent. sugar may be obtained; is one of the most elastic woods found in Nicaragua. It is used for drum hoops, canes, etc. The tree seldom attains a height of twenty feet, and about twelve inches in diameter.

(15.) *Madera-Negra.*—One of the most useful trees found in Nicaragua, not only on account of its durability, strength and excellency for fire wood, giving out intense heat; but also from its method of growth. It is about the only tree used to shade the

chocolate trees. It has a rapid growth, and is early produced from the seed. Mostly used for railroad ties, posts for houses, fence posts, foundations, etc. Has a dark, yellowish color in the heart, is fine grained, heavy and tough. It grows with oblong cavities wasting a good deal of the wood when being dressed. However, straight logs, 1 foot square and 30 feet high can be obtained.

(16). *Madrono.*—There are two kinds, white and dark. It has a fine grain, and is heavy. Its strength may be seen from the tests in torsion and by transverse stress. Its growth is irregular and branching.

(17.) *Mahogany.*—This is too well known to demand description. In Nicaragua it is fairly well distributed. The best and most valuable is exported to a considerable extent from the Mosquito territory, where it grows abundantly, and to its fullest size. It is also found along the Pacific Coast in considerable quantities

(18.) *Moran.*—Solid and fine grained wood of a beautiful yellow color. After it has been turned, it looks as if it had been polished; planes very easily. It is exported in great quantities as a dye-wood. Is often used for columns. Attains a height of from 30 to 35 feet. and a diameter of from 12 to 18 inches.

(19.) *Nacascolo.*—The wood is extremely heavy, very fine grained, and of a handsome dark color. Its toughness is shown by the test in torsion. The fruit is known by the names of *Nacascolo* or *Dividi*, and used for dyeing purposes when dry. It is one of the largest of hard-wood trees. Its trunk, although irregular in growth, and seldom over twenty feet to the point where it branches, is 6 feet in diameter. It attains a height of 60 feet, and is found more abundantly on the Atlantic Coast. Is an excellent wood for railroad ties.

(20.) *Nancite.*—Has a soft pink color, fine grain and works very easily. The tree is small, grows on arid hills, and seldom attains 30 feet height. Its bark is used for tanning, and its fruits are to the Nicaraguenses what cherries are to the North Americans.

(21.) *Nispero.*—It may be said that there are two kinds, wild and cultivated. Large fruit tree of a thick and handsome foliage. The trunk is straight and free from limbs. The tree attains a height of 60 feet and a diameter of 2 feet. It is abundant all through the country in farms near the towns and in the wild

forests. Exclusively used for wharves, bridges and posts. Resists moisture equal to any of the hard woods, and is said to petrify in the water. The wood is of an exceedingly fine grain, has a beautiful red color, and is very easy working It behaved the best of any under compression, bulging out considerably before showing any sign of shearing or split.

(22.) *Oja-tostada*.—Has a very light pink color, is fine grained and light. It is one of the most elastic and tough woods tested, as may be seen from the tests by transverse stress and by compression. It is very good for light and strong constructions.

(23.) *Palo de Arco*.—The sample tested planed easily in parts, and in parts less readily, probably on account of being green. Is hard, has a fine grain, and a light red color. It is used for construction where easy of access. It grows along the coast, and in the coast range of mountains, attaining a height of 30 feet and 15 inches in diameter.

(24.) *Piedra*. (Stone.)—Has a fine grain, is heavy and strong, of a yellowish color in the sap, and deep red in the heart. Turns very smoothly and is one of the hardest and heaviest woods known and yet not difficult to turn or plane. The tree attains a height of 40 feet, and has a diameter of from 15 to 18 inches. It is imperishable. Used in many places for pillars and transverse beams of houses on farms distant from towns where it is easy of access. Is abundant on the hills along the coast on the Pacific slope. There are two varieties. It is an excellent wood not only for interior decoration or for heavy furniture on account of its beautiful color and fineness of grain, but also for heavy constructions, as for foundations for engines or heavy machinery.

(25.) *Pochote*.—Tree of enormous dimensions. The wood is similar to the cedar, but much softer. It is used, however, in housework for doors, walls, floors, shingles, etc.

(26.) *Quiebra-hacha* (axe-breaker). There are two kinds, red and black. The latter, which was tested in three ways, is a most wonderfully tough wood. It has a color and appearance like the black-walnut, and its grain is similar to that of the oak. It planes beautifully smooth, and has a pleasing appearance, on account of its dark streaks. The red kind, which grows very straight and spreads considerably, reaches a height of 50 feet, and from 12 to 15 inches diameter. The dark kind, which spreads still

more, seldom attains a height of 40 feet. Their name, axe-breaker, indicates their toughness; for in cutting or felling them, the axe is often broken. In cutting the samples received, two axes were nicked to the extent of one-half to three-fourths of an inch. The wood is durable and used for ties, poles, etc., and in posts for houses. One piece that had been for sixty-seven years in a clay soil was found still sound when sawed. The tree is common throughout the state.

(27.) *Quita-Calson*.—Its powder acts as a purgative. The tree attains a height of 30 or 35 feet, branching at 15 or 20 feet from the trunk, and often has a diameter of 2 feet. It is abundant along the coast. It is used for boards where not exposed to the weather; it will not resist moisture.

(28.) *Roble*.—Light colored wood of a curly and beautiful grain. It is pink in color and used in house-building. The tree has exceedingly large leaves, 14 inches long and about 7 inches wide, is often 50 feet high, and from 12 to 15 inches diameter. Is abundant along the coast.

(29.) *Ron-ron*.—This is one of the largest of hard-wood trees growing on the shores of the rivers of the Departmento of Chontales on the Atlantic slope. It reaches a height of 50 or 60 feet, and often a diameter of 3 feet. Dark, fine-grained wood, strong, heavy and durable. Is used in cabinet work, turns very easily, and is susceptible of polish. It turns dark with age.

(30.) *Tempisque*.—This tree is of historical interest in Nicaragua, and is one of the largest found in the tropical forests. It attains a height of seventy-five feet or more. The trunk is irregular and seldom reaches twenty feet to the beginning of the largest branches. It has a diameter of 6 feet. The wood is fine grained, hard and very excellent for desks and other articles of cabinet work. Like the mahogany, it turns dark in a few years, and is equally durable. The cattle eat its fruit.

(31.) *Tiguilote*.—Light wood, grows about 30 feet high, and over 12 inches in diameter; good wood for carriages. It is used for fence posts, it easily roots when set with care, thus making a permanent fence and a pretty grove.

(32.) *Zapotillo*.—Of a light mahogany color, has a fine grain, and is light. Attains a height of 40 feet and 1 foot in diameter. It is not very much used.

(33.) *Zopilote* (Buzzard).—Coarse, long-grained wood, but of compact layers when viewed in cross-section. It has a greenish color. Turns and planes fairly well. The wood is used only in neighborhoods where more useful woods are scarce. When unexposed or when well seasoned and protected with paint, it would probably be a valuable wood, as it ran above the average in torsion, was among the highest in compression, and stood well under transverse stress. It attains a height of about 40 feet and 1 foot in diameter.

The Transverse Stress tests were made in the Transverse testing machine of the Messrs. Fairbanks, designed for Prof. Thurston. It consists of a Fairbanks' scale combination with a pointer and beam at the end to secure perfect balance. The whole machine rests upon a wooden frame; upon the platform rests a cast iron cross beam, and upon this slide the supports, which are set and secured by bolts at the required distance apart. The test piece is placed upon the mandrels, which rest on the supports set at the required distance. The loads are put in the scale, and equilibrium is established by the elastic resistance of the piece offered against the pressure transmitted through the screw and pressure block by means of the lever. The screw passes through a nut, and terminates in a sliding piece. The cast iron columns serve as guides to the pressure block. The whole is made stable by wrought iron braces bolted to the wooden frame. The deflections of the piece are measured by the linear advance of the screw, by means of a graduated wheel. The pitch of the screw was found to be equal to 0·33297 inches, and the wheel was graduated into 333 equal divisions, thus reading to $\frac{1}{1000}$ of an inch, with an error of 0·0001 of an inch. The pointer clamped to the screw is placed over the starting division in each case, and after the wheel has been turned and equilibrium established, the reading is taken. This is a very convenient way of reading the deflections, giving the difference directly. The test pieces were planed by hand by an expert, Mr. Kerr, and afterwards measured by means of a micrometer screw reading to $\frac{1}{1000}$ of an inch.

With all the data required, we obtained the results in the same way as in compression tests, by plotting the curve to each test, with loads as ordinates and the deflections as abscissas. This gives the elastic limit more exactly than in any other way. It also

shows at a glance the behavior, strength, elasticity, etc., of the material tested.

DETAILS OF TRANSVERSE STRESS TESTS.

(1.) *Carbon.*—28-inch supports. Green sample from the sap, and with a few small knots on top. Like the other, it broke just after having brought the beam up by its elastic resistance, under 650 pounds, and deflected 1·011 inches. Remained unbroken.

(2.) ——.—25-inch supports. A very well seasoned piece, but slightly weakened by a knot where it first gave way. The first rupture occurred at 950 pounds on the weak part. The second under 1,150 pounds with a long and several other small splinters on tension side. Total deflection, 1·687 inches.

(3.) *Chaperno.*—24-inch. A very good sample as regards soundness and seasoning. Cross grained. Broke under 3,700 pounds, with a deflection of 0·496 inch. Broke gradually in small splinters from the bottom side upwards, and crushed slightly on top also.

(5.) *Cortez.*—24-inch. A large sample from near the heart. Excepting two knots on thickness and bottom sides respectively, and checked on sap line on top, it was a fine sample. Its toughness is shown by its behavior under load. Reached the elastic limit at 2,500 pounds, broke at 4,300 pounds, with a deflection of 0·443 inch. Second rupture occurred under 4,650, with a deflection of 1·3975 inch. By diminishing the loads it might have given more ruptures without breaking completely. Broke in several adhering splinters on tension side.

(7.) *Guachipilin.*—11-inch supports. Good sample. The first rupture occurred under 1,800 pounds load with 0·462 inch deflection. After the first rupture it showed a good deal of elasticity in resisting the loads and gradually ruptured slightly under 2,050 pounds. The reason we took this latter for the rupturing load is on account of the behavior after the first rupture, which latter was very light, and on account of a weak point. Both ruptures were very light splinters, and the piece might have shown still more tenacity if the load had been diminished. But here, as in most cases, we were after first rupture only. Almost any kind of wood will behave in the same way if so treated, unless it is very brittle.

(8.) *Guapinol.*—24-inch supports. An inferior sample, knotty near the middle, checked on top, and with a few worm holes. Broke under 1,600 pounds with a deflection of 0·699 inch and with a few splinters on tension side.

(9.) *Guayabo de Monte.*—24-inch supports. The test piece was planed from a green limb. It was checked and knotty on either side of middle line in tension side. The first rupture occurred on account of cross-grain at 660 pounds, with a deflection of 0·477 inch. Ruptured with only one splinter across the bottom side.

(11.) *Jenisero.*—24-inch. Broke at 1,600 pounds, with a deflection of 0·426 inches. When under 1,600 pounds load, brought the scale up when pulling the lever arm, but immediately afterwards broke suddenly in two splinters. It evidently is very brittle.

(18.) *Moran.*—15-inch supports. A very sound and beautiful natural-colored piece of wood. Ruptured in light splinters under 2,600 pounds, with a deflection of 0·432 inches. Remained unbroken and could have still shown tenacity in successive ruptures.

(20.) *Nancite.*—32-inch supports. A good sample. Broke square on tension side, in two pieces, and very suddenly, after having offered elastic resistance to 2,200 pounds, and deflected 1·0765 inches.

(23.) *Arco.*—24-inch. Straight-grained sample, with two knots on bottom side. Broke at 2,000 pounds, with a deflection of 0·679 inches. Second rupture occurred under 1,100 pounds load, with a deflection of 1·116 inches. Ruptured with close splinters on tension or bottom side.

(26.) *Quiebra hacha negro.*—25-inch supports. Excepting a light streak of sap wood on bottom side, where it first gave away, it was a very sound sample. Its first rupture occurred when under 2,450 pounds, with a deflection of 1·693 inches. A second rupture occurred at 2,550 pounds, with a sudden crash and with a deflection of 2·080 inches. It is worth observing that the second rupture occurred with a larger stress than in the first one. The very finely intermingled narrow and regular splinters across the bottom side very fairly exhibit the high tenacity, ductility, as I may be allowed to say, and the uniformity of strength, cohesion and grain of this peculiar wood. Its rupture could very well be taken as the standard rupture of tough woods.

(27.) *Quita-Calson.*—21-inch supports. Season-checked on top,

TESTS BY TRANSVERSE STRESS.

	Wood.	Dist'nce between supports l	Depth h	Breadth b	Stress. E. Limit P	Stress. Rupture P'	Deflection at— E. Limit. d	Deflection at— Rupture. d'
		in.	in.					
1	Carbon,	28	1·235	1·470	300	650	0·392	1 011
2		25	1·225	1·215	500	1050	0·478	1·354
3	Chaperno,	24	2·000	1·994	2800	3700	0·36	0·496
4	Chiquirin,	24	1·772	1 779	1800	2400	0·420	0·611
5	Cortez,	24	1·740	1 745	2500	4300	0·443	1·073
7	Guachipilin,	12	1·237	1·237	1200	2050	0·277	0·761
8	Guapinol,	24	1·498	1·498	900	1600	0·335	0 699
9	Guayabo de Monte,	24	1·495	1·495	300	710	0·157	. .
11	Jenisero,	24	1·742	1·742	1000	1600	0·426	0·810
13	Laurel blanco,	28	1·775	1 730	1400	2150	0·139	0·265
14	Lligualtil,	30	1·218	1·218	300	750	0·552	3·284
18	Moran,	15	1·627	1·620	1600	2600	0·237	0 432
20	Nancite,	32	1·98	1·983	1200	2200	0·4385	1 076
22	Oja-tostada,	24	1·239	1·239	400	850	0·352	1·656
23	Palo de Arco,	24	1·459	1 492	1200	2000	0·382	0·679
26	Quiebra-hacha-negro,	25	1·479	1·473	1200	2450	0·395	1·693
27	Quita-calson,	21	1·224	1.225	400	750	0 322	0·811
28	Roble,	30	1·772	1·768	1000	1600	0 615	1·217
30	Tempisque,	24	0·995	0·978	300	700	0·459	1·605
32	Zapotillo,	28	1·734	1·734	900	2100	0·318	1·139
33	Zopilote,	11	1·225	1.233	1450	2550	0·202	0·462
34	Guacuco,	30	1·48	1·480	500	1170	0·438	1·526
35	Escobillo,	30	1·745	1·741	0800	1850	0·216	0·826

	Wood.	Stress in outermost Fibre per Square Inch, at— E. Limit. $p = \frac{3Pl}{2bh^2}$	Stress in outermost Fibre per Square Inch, at— Rupture. $p' = \frac{3P'l}{2bh^2}$	Total Elastic Resilience $U = \frac{Pd}{2}$	Modulus of Elasticity. $E = \frac{Pl^3}{48\,d\,I}$
		lbs.			
1	Carbon,	5613	12162	58	1514400
2		10272	21571	119	1824400
3	Chaperno,	12575	16617	504	1672500
4	Chiquirin,	11600	15467	378	1496300
5	Cortez,	17025	29294	553	2119800
7	Guachipilin,	11411	19490	166	614550
8	Guapinol,	12206	21699	150	1858400
9	Guayabo de Monte,	3232	7649	23	1322000
11	Jenisero,	6803	6803	213	879780
18	Moran,	8385	13624	189	815100
20	Nancite,	7409	13583	263	1456500
22	Oja-tostada,	7571	16088	70	1665500
23	Palo de Arco,	13602	22670	229	2342900
26	Quiebra-hacha-negro,	13966	28514	237	2490200
27	Quita-calson,	6865	12872	64	1280300
30	Tempisque,	11154	26026	68	2344600
33	Zopilote,	12479	22730	141	1017100

and knotty on either side of middle line on the thickness side. Broke just under 750 pounds, with 0·811 inches deflection.

(33.) *Zopilote.*—11-inch supports. With a knot near one support gave away by shearing at the place when under 2,550 pounds. Stopped the test at this point and took this as the rupturing load.

The compression tests were made on the Olsen machine of 14,000 pounds capacity. The machine consists of four columns bolted to a plain cast-iron bed, and supporting on top a plate, in the middle of which one end of the test piece, if for tension, or the rod which holds the measuring apparatus are held by means of steel wedges.

Through the four angles of this bed and through those of that below pass four screws. To these latter is secured a plate, which pulls or compresses the piece, as the case may be. The plate rests upon four knife edges, on three beams or levers, and their ends rest together upon a link hung from knife-edges on each side of another beam, which latter is linked to the end of the scale in the same way. The machine is very sensitive. The scale is divided into divisions of five pounds. The load is applied by means of a crank or a lever, turning a central wheel geared to four others, one on each screw. A powerful leverage and a steady vertical motion of the plate is obtained. The deflections were measured by means of micrometer screws, using the electrical contact. I quote Prof. Thurston's full description of the instrument:

"The instrument consists essentially of two very accurately-made micrometer screws, working snugly in nuts secured in a frame which is fastened to the head of the specimen by a screw clamp. It is so shaped that the micrometer screws run parallel to and equidistant from the neck of the specimen on opposite sides. A similar frame is clamped to the lower head of the specimen, and from it project two insulated metallic points, each opposite one of the micrometer screws. Electric connection is made between the two insulated points and one pole of a voltaic cell, and also between the micrometer screws and the other pole. As soon as the micrometer screw is brought in contact with the opposite insulated point, a current is established, which fact is immediately revealed by the stroke of an electric bell placed in the circuit. The pitch of the screws is 0·02 of an inch, and their heads are divided into 200 equal

parts; hence a rotary advance of one division on the screw head produces a linear advance of one ten-thousandth (0·0001) of an inch.

"A vertical scale, divided into fiftieths of an inch, is fastened to the frame of the instrument, and set very close to each screw head and parallel to the axis of the screw; these serve to mark the starting point of the former, and also to indicate the number of revolutions made. By means of this double instrument, the extensions can be measured with great certainty and precision, and irregularities in the structure of the material, causing one side of the specimen to stretch more rapidly than the other, do not diminish the accuracy of the measurements, since half the sum of the extensions indicated by the two screws is always the true extension caused by the respective loads."

The size of test pieces advised for compression varies with different authorities, the limit of the ratio of the length to the diameter being five times the diameter. The compression test should crush the piece down or shear it at 45°, but even with the ratio used—the length equal to twice the diameter, as given and used by Prof. Thurston—the piece showed a slight buckling in some cases.

We have obtained the results, from each test by plotting a curve, taking the loads as ordinates and the deflections as abscissas. In this way we see the behavior of the piece at a glance, by the curve, and find the elastic limit very accurately. This latter was obtained by drawing a straight initial line when necessary, and taking it as the point where the curve leaves the line.

We have given not only the results derived from the most common formula used in designing, or used indirectly, but also the original data of size of test piece, the actual loads, unit strains and stresses as they may be found convenient in some cases and for further information if desired. The formulæ from which the results were derived are set at the head of the tables.

	Name.	Original		Final	Stress.			Strain.		
		Length.	Diameter.	Length.	E. Lim.	Maxim.	Break'g	E. Limit.	Maxim.	Breaking.
2	Cedar,	1·656	0·844	1·6273	2100	2300	2300	0·0189	0·0289	0·0289
5	Cortez,	1·625	0·828	1·5815	5500	8100	8100	0·0224	0·0435	0·0435
6	Granadillo-negro,	1·552	0·729	1·4733	4000	6500	6070	0·0115	0·0307	0·0795
7	Guachipilin,	1·583	0·732	1·5546	3000	5000	5000	0·0102	0·0289	0·0289
9	Guayabo de Monte,	2·235	1·125	2·1893	6000	8500	8500	0·0191	0·0460	0·0460
11	Jenisero,	1·506	0·794	1·4632	3000	4000	4050	0·0179	0·0341	0·0432
14	Lligualiil,	1·609	0·828	1·5157	4200	6325	6325	0·0178	0·0804	0·0936
15	Madera-negra,	1·609	0·812	1·5416	5500	6700	6650	0·0326	0·0574	0·0677
16	Madrono,	1·625	0·812	1·5638	4800	6600	6000	0·0156	0·0315	0·0612
21	Nispero,	1·625	0·828	1·5760	3500	7000	7000	0·0142	0·0490	0·0490
22	Oja-tostada,	1·218	1·0859	2·1573	5000	8000	7800	0·0130	0·0316	0·0613
26	Quiebra-hacha,	1·625	0·8281	1·5776	5400	8600	8375	0·0225	0·0864	0·0474
27	Quita-calson,	2·224	1·119	2·1743	5000	8000	7600	0·0130	0·0318	0·0495
29	Ron-ron,	1·625	0·828	1·1823	4200	5900	5900	0·0165	0·0427	0·0427
31	Tiguilote,	2·219	1·126	1·1941	3800	5000	5000	0·0164	0·0251	0·0251
36	Guanacaste,	1·969	0·817	1·5560	3000	3700	3700	0·0135	0·0409	0·0409

	Wood.	Unit Stress.			Unit Strain Elastic Limit.	Modulus of Elasticity.	Modulus of Resilience
		E. Limit. $p = \frac{P}{F}$	Maxim. $p' = \frac{P'}{F'}$	Breaking. $p'' = \frac{P''}{F''}$	$\epsilon = \frac{\lambda}{L}$	$e = \frac{p}{\epsilon}$	$U = \frac{p\,\lambda}{2\,L}$
1	Carbon,	5600	9800	9585	0·0069	804860	19
3	Chaperno,	2100	11500	11500	0·0035	593540	3
8	Guapinol,	7800	12000	12000	0·0074	1051600	28
10	Guiliguiste,	6000	8800	8800	0·0067	882940	20
12	Jicaro-sacaguacal,	4000	7800	7800	0·0096	414020	19
20	Nancite,	6000	8000	8000	0·0072	824340	21
21	Nispero,	5600	10275	10000	0·0077	723550	21
21	Nispero,	7000	14000	14000	0·0087	801050	30
33	Zopilote,	7200	10800	10500	0·0099	721370	35

	Wood.	Unit Stress. E. Limit. $p = \frac{P}{F}$	Maxim. $p' = \frac{P}{F}$	Breaking $p'' = \frac{P''}{F}$	Unit Strain Elastic Limit. $E = \frac{\lambda}{L}$	Modulus of Elasticity. $E = \frac{p}{e}$	Modulus of Resilience $U = \frac{p\lambda}{2L}$
2	Cedro, ...	4200	4600	4600	0·0114	367190	18
5	Cortez, ...	11000	16200	16200	0·0137	797990	75
6	Granadillo-negro, .	8000	13000	12140	0·0074	1080300	29
7	Guachipilin, ...	6000	10000	10000	0·0064	931470	19
9	Guayabo de Monte, .	6000	8500	8500	0·0085	702180	25
11	Jenisero, ...	6000	8000	8100	0·0118	504880	35
14	Lligualtil, ...	8400	12700	12650	0·0110	759440	46
15	Madera-negra, . . .	11000	13400	13300	0·0202	543010	111
16	Madrono, ...	9600	13200	12000	0·0096	1000000	46
21	Nispero, ...	7000	14000	14000	0·0087	801050	30
22	Oja-tostada, ...	5000	8000	7800	0·0058	853320	14
26	Quiebra-hacha; . . .	10800	17200	16740	0·013846	780000	74
27	Quita-calson, . . .	5000	8000	7600	0·0058	855310	14
29	Ron-ron, ...	8400	11800	11800	0·0101	827270	42
31	Tiguilote, ...	3800	10000	10000	0·0073	514210	14
36	Guanacaste, ...	6000	7400	7400	0·0084	709730	25

	Wood.	Original. Length. L	Diameter D	Final Length. L	Stress. E. Limit. P	Maxim. P'	Breaking. P''	Strain E. Limit. λ
1	Carbon, . . .	2·2421	1·128	2·1562	5600	9800	9585	0·0156
3	Chaperno, . .	2·2611	1·1245	2·2096	2100	11500	11500	0·0080
8	Guapinol, . .	2·2516	1·3115	2·2036	7800	12000	12000	0·0167
10	Guiliguiste, .	2·2515	1·128	2·2012	6000	8800	8800	0·0153
12	Jicaro-sacaguacal, ...	1·625	0·8437	1·5534	2000	3900	3900	0·0157
20	Nancite, . . .	2·2532	1·1292	2·2238	6000	8000	8000	0·0164
21	Nispero, . . .	2·2611	1·1235	1·9522	5600	10275	10000	0·0175
21	Nispero, . . .	1·625	0·8281	1·5760	3500	7000	7000	0·0142
33	Zopilote, . . .	2·2704	1·126	2·2143	7200	10800	10500	0·0180

The torsion tests were made in the autographic testing machine of Prof. Thurston: It consists of two angle frames united at their vertices by a cast-iron rod and rigidly bolted to a heavy cast-iron bed, thus making the machine very firm. These two angles have the bearings in line with the jaws or wrenches which hold the piece to be tested by means of steel wedges put from opposite sides. The test piece is put in line before securing it rigidly between the jaws, by means of centres in each jaw, one resting on a spiral spring and the other turned by a screw which projects out of the frame, thus enabling to place the piece symmetrically and directly in line with the axis of rotation.

The outer end of one of the jaws is connected to a worm-wheel, the rotation to which is imparted through the worm by means of the crank. The other jaw carries the pendulum, to which is connected, a little below the jaw, the pencil which is held by a spring, tight against the sides of the guide curve. This curve is made so that when the pencil rolls on it, in virtue of the swinging of the pendulum through the test piece, the ordinates which are recorded upon a cross-section paper carried by a drum on the opposite jaw or on the one connected to the worm wheel, are proportional to the moments about the axis of the test piece. The machine, by the tracing of a simple curve, tells all the characteristics of the test piece. The circumference of the drum is equal to thirty-six inches, and the inches in the paper are divided into ten equal parts, thus making each inch of paper equal to 10°. The vertical lines are also divided in inches and each into tenths.

When the piece is secured between the clamps, the crank is turned by hand with a uniform motion and a slow rotation, interrupted only by the rupturing of the piece, is given to it, causing the pendulum to swing up on one side. This measures the resistance to torsion of the test piece which is recorded autographically in the paper.

To make these tests, we took off the bob from the pendulum, as it offers too large a moment for the torsional resistance of the woods for the size of test piece used. Before making the tests, we found the necessary constants of the machine to work out the results of tests, as follows: The pendulum without the bob was supported horizontally by a column, which rested on a scale. Thus, the maximum moment of the pendulum was weighed, and the corresponding ordinate in the curve observed:

Lever arm,	48 inches.
Weight of column with lever arm,	52·75 pounds.
" supporting columns	21·5 "
" lever arm, or pendulum,	31·25 "
Hence maximum moment,	1, 500 inch-pounds.

Maximum ordinate traced by the pencil, or ordinate corresponding to horizontal position of the pendulum — 4·3 inches. Therefore, one inch of ordinate = 348·837 inch-pounds.

We found the friction of the machine by means of a delicate spring balance, attached at a distance of fifty inches from the

centre of suspension. The pendulum was pulled just far enough to overcome friction alone. After several trials, it was found to be equal to 0·25 pounds. Thus, the friction of the machine is 12·5 inch-pounds, which friction is added, in every case, to the moments recorded by the pencil.

The absolute errors in the size of the test pieces vary by excess from above one-thousandth ($\frac{1}{1000}$) of an inch up to a little above one-hundredth (0·01) of an inch.

We have put down the moments at the elastic limit and at the maximum before rupture; also the angles of torsion at the elastic limit, maximum before rupture, and final rupture with the corresponding elongations of the outermost fibres for the first three angles. As a matter of detail, we have observed those which reached the final rupture with a higher moment after the first rupture, and those that did not offer a higher resistance. The names used express the character of the four critical points to which a material is subjected under an increasing stress.

Not being able to put in the strain diagram, we have endeavored to write out for illustration the behavior of several pieces under stress, and their mode of rupture as concisely as possible in the details of torsion tests. These may be more valuable than the numerical results. The torsion tests give a better and more general idea of all the properties of strength and elasticity of the woods than any other test, as, in this case, they are compelled to write for themselves their "own story."

DETAILS OF TORSION TESTS.

(1.) *Carbon.* $d = 0{\cdot}6271$.—Test piece turned from a large sample near the heart. Very sound in the turned part. Elastic limit, maximum and rupture occurred under the same moment. From this and by breaking in two splinters it shows it is a brittle wood. It reached a moment at the latter points of 200·87 inch-pounds, at an angle of 7°·5 and gave away completely at 13°·2 with no higher moment. Its curve was at 45° from the axis of angles and was short-wavy all along.

(2.) ————.—With a short wavy and parabolic curve reached its elastic limit at 7°·11 under a moment of 186 inch-pounds, and reached a maximum of 190 inch-pounds moment, which kept constant for about 8°, when it came down and ruptured. Fairly regular stiff rupture.

(3) *Chaperno.* $d = 0.6278$.—Turned from a large sample and very sound piece. It rose with a 45° wavy curve up to 104·9 inch-pounds when it reached the elastic limit. Went up to a maximum of 124·128 inch-pounds, which kept constant until final rupture, splintered at 17°·3.

(5.) *Cortez.* $d = 0.6278$.—Turned from a large sample near the heart. Very sound piece. It rose with a 45° curve and slightly wavy but uniform, reaching the elastic limit at 214·82 inch-pounds at an angle of 5°·9. Ruptured at 28° and splintered at 41°, reaching afterwards a higher moment, which kept constant till final rupture. Fibrous and stiff rupture, shearing a plug of same cross section as the turned part from the shoulder.

(8.) *Guapinol.* $d = 0.5645$.—With a slightly parabolic curve at 45° angle, reached its elastic limit at 6° with a 183 inch-pounds moment, which kept constant until first rupture and reached a little higher moment before final rupture. Gave away with wide fibrous splinters.

(12.) *Ficaro-sacaguacal.*—The test piece was turned from a green limb. It rose with a parabolic line and very much inclined toward the axis of strains reaching at the elastic limit a moment of 103·2 inch-pounds. Reached a higher moment, which kept constant until final rupture at 155°, when it completely broke irregular and stiff.

(13.) *Laurel.* $d = 0.631$.—Dark color. With a low sloping curve, but uniform, reached the elastic limit at 4° angle and under a moment of 82·268 inch-pounds. This was its maximum resistance and kept constant until ruptured at 20°. Uniform square rupture around the shoulders without projecting splinters. Gave way entirely at 105° angle.

(17.) *Mahogany.* $d = 0.6358$.—A very sound piece, turned from a large sample. It rose with a long wavy line up to 78·779 inch-pounds, its elastic limit at 3° angle. Reached a higher moment of 82· inch-pounds at 6°·7 when it ruptured. It splintered at a still little larger moment at 27°·6. Fibres wide and stiff, and rupture irregular.

(18.) *Moran.* $d = 0.6256$.—A very sound piece. With a curve above 45° angle with the axis of strains reached its elastic limit at 2° under a moment of 82·27 inch-pounds, which kept constant for 1·5, when it rose to 88·95 inch-pounds moment, and gave away for

the first time. However, it still reached about twice as large a moment which kept constant till final rupture. Fibrous and tough rupture.

(24.) *Piedra* (Stone). $d = 0{\cdot}6257$.—A piece turned from near the heart and very sound. It rose with a parabolic short wavy line up to the elastic limit, when it had a moment of 227 inch-pounds at an angle of 9°·7 It reached a maximum moment of 228 7 inch-pounds at an angle of 11°, and very soon lowered its moment to 221·8 inch-pounds, which kept constant until it splintered at 50°. Wide splinters and stiff rupture, but square around the shoulders.

(26.) *Quiebra-hacha.* $d = 0\,6268$.—A very sound piece. It rose with a parabolic curve above 45°, with the axis of strains up to 166 inch-pounds moment, its elastic limit, and kept reaching higher and higher moments by regular intervals up to a maximum after first rupture of 319·479 inch-pounds without giving way completely. Brushy, regular break and very tough.

(29.) *Ron-ron.*—Dry and sound piece. Rose with a straight line up to 82·26 inch-pounds moment at an angle of 1°·5, and kept a constant moment till final rupture. Broke with brittle fracture in two pieces, without showing any fibre.

(32.) *Zapotillo.*—The test-piece turned from a large sample, $d = 0{\cdot}6258$ inch; had a small knot on one end, but very sound otherwise. It reached its maximum at the elastic limit at an angle of 5°·5 from the origin, rupturing with the same moment at angle of 9°. It kept a constant moment for about 80°, when it reached a little higher moment holding it till final rupture. Fibrous rupture.

(33.) *Zopilote.*—At first rose with a straight line below 45°, and turned parabolic near and after the elastic limit. First ruptured at 28° angle under a 106 inch-pounds moment and raised it slightly, keeping the latter constant for over 160. A very thready and tough rupture.

TESTS BY TORSION.

	Wood.	Moments of Torsion in in.-lbs.		Angle of Torsion in Degrees.			Maximum Shearing Stress.	
		E. Limit.	Max. before Rupt.	E. Lim	Max. before Rupt.	First Rupt.	Elastic Limit.	Maximum before Rupture.
		$(P_s)_E$	$(P_s)_M$	a	a_1	a_2	$p_s = \frac{2}{\pi r^3} \times (P_s)_E$	$p_s = \frac{2}{\pi r^3}(P_s)_M$
2	Cedar, . .	43·89	45 63	3·6	8·4	8·4	915	952
5	Cortez, . .	68·3	71·80	3·3	19·	27·5	1424	1497
7	Guachipilin,	82·2 8	148·54	2·6	49·	49·	1716	3098
9	Guayabo de Monte, .	54·36	64·82	4·5	5·5	26·5	1133	1352
13	Laurel-macho, .	68·31	71·8	2 8	4·1	4·1	1424	1497
15	Madera-negra, .	141·57	141·57	3·6	13·4	17·4	2953	2953
16	Madrono, .	99·71	103·19	4·5	29·	35·0	2080	2152
19	Nacascolo,	145·06	145·06	2·4	2·4	16·1	3026	3026
20	Nancite, .	61·34	68·3	2·7	12·	12·	1279	1424
21	Nispero, .	103·89	193·89	7·2	5·	9·5	4044	4044
22	Oja-tostada,	52·616	54·36	2·7	14·5	19·5	1097	1133
25	Pochote, .	47·38	50·87	5·0	5·8	5·8	988	1061
26	Quiebra-hacha (yellow),	152·03	152·03	5·0	5·	9·3	3171	3171
28	Roble, . .	54·36	54·36	3·3	3·3	12·	1133	1133
31	Tiguilote, .	33 43	43·87	5·4	17·5	17·5	697	915
36	Guanacaste,	68·31	71·8	2·25	3·2	3·2	1424	1497

	Wood.	Moments of Torsion in in.-lbs.		Angle of Torsion in Degrees.			Maximum Shearing Stress.	
		E. Limit	Max. before Rupture	E. Limit	Max. before Rupture	First Rupture	Elastic Limit.	Maximum before Rupture.
		$(P_s)_E$	$(P_s)_M$	a	a_1	a_2	$p_s = \frac{2}{\pi r^3}(P_s)_E$	$p_s = \frac{2}{\pi r^3}(P_s)_M$
1	Carbon, . .	200·8	200·8	7·5	7·5	7·5	4190	4190
2		186·92	190·4	7·11	8·5	8·5	3899	3972
3	Chaperno, .	104 9	124·1	3·4	5·7	7·3	2189	2589
5	Cortez, . .	214·8	214·8	5 9	5 9	28·0	4481	4481
7	Mahogany,	78·7	82·2	3·0	6·7	6·7	1643	1716
8	Guapinol, .	183·4	183·4	6·0	18·2	18·2	3826	3826
12	Jicaro-sacaguacal, .	103·2	110·1	20·	22·0	22·0	2153	2298
13	Laurel, dark,	82·2	82·2	4·0	4·0	20·0	1716	1716
18	Moran, . .	82·2	88·9	2·0	4·2	4·2	1716	1855
24	Piedra, . .	227·0	228·7	9·7	11·0	11·	4736	4772
26	Quiebra-hacha, . .	166·	166·0	8·0	8·0	8·0	3463	3463
29	Ron-ron, .	82·2	82·2	1·5	23·5	23·5	1716	1716
32	Zapotillo, .	99·7	99·7	5·5	5·5	9·0	2080	2080
33	Zopilote, .	94·4	106·6	5·7	28 0	28·0	1971	2225

	Wood.	Extension of outer Fibre. E. Limit. $\lambda = \sqrt{1 + a^2(0{\cdot}000029747)} - 1$	Extension of outer Fibre. Max. before Rupture. $\lambda = \sqrt{1 + a^2(0{\cdot}000029747)} - 1$	Extension of outer Fibre. First Rupture. $\lambda = \sqrt{1 + a^2(0{\cdot}000029747)} - 1$	Modulus of Elasticity. $E_a = \frac{(P_a)E}{a} \times \frac{l}{I_p}$	Total Elastic Resistance. $\frac{(P_a)E \times a}{2}$
2	Cedar, . . .	. . .	. . .	. . .	46635	1
5	Cortez, . . .	. . .	. . .	. . .	79161	2
7	Guachipilin, .	. . .	. . .	. . .	152358	2
9	Guayabo de Monte, . .	. . .	. . .	. . .	46203	2
13	Laurel-macho,	. . .	. . .	. . .	93310	1
15	Madera-negra,	. . .	. . .	. . .	150407	4
16	Madrono, . .	. . .	. . .	. . .	84748	4
19	Nacascolo, .	. . .	. . .	. . .	231175	3
20	Nancite, . .	. . .	. . .	. . .	86893	1
21	Nispero, . .	. . .	. . .	. . .	102997	12
22	Oja-tostada, .	. . .	. . .	. . .	74533	1
25	Pochote, . .	. . .	. . .	. . .	36243	2
26	Quiebra-hacha (yellow), .	. . .	. . .	. . .	116297	6
28	Roble, . . .	. . .	. . .	. . .	63003	1
31	Tiguilote, . .	. . .	. . .	. . .	23678	1
36	Guanacaste, .	. . .	. . .	. . .	116119	1

	Wood.	Extension of outer Fibre. E. Limit. $\lambda = \sqrt{1 + a^2(0{\cdot}000029747)} - 1$	Extension of outer Fibre. Max. before Rupture. $\lambda = \sqrt{1 + a^2(0{\cdot}000029747)} - 1$	Extension of outer Fibre. First Rupture. $\lambda = \sqrt{1 + a^2(0{\cdot}000029747)} - 1$	Modulus of Elasticity. $E_a = \frac{(P_a)E}{a} \times \frac{l}{I_p}$	Total Elastic Resistance. $a = \frac{(P_a)E \times a}{2}$
1	Carbon, . . .	. . .	. . .	. . .	102440	13
2		. . .	. . .	. . .	100551	11
3	Chaperno, . .	. . .	. . .	. . .	118050	3
5	Cortez, . . .	. . .	. . .	. . .	139270	11
8	Guapinol, . .	. . .	. . .	. . .	116920	9
12	Jicaro-sacaguacal, . .	. . .	. . .	. . .	19735	18
13	Laurel (dark),	. . .	. . .	. . .	78663	2
17	Mahogany, .	. . .	. . .	. . .	100440	2
18	Moran, . . .	.	. . .	. . .	157330	1
24	Piedra, . . .	. . .	. . .	. . .	89522	19
26	Quiebra-hacha,	. . .	. . .	. . .	79363	11
29	Ron-ron, . .	. . .	. . .	. . .	209750	1
32	Zapotillo, . .	. . .	. . .	. . .	69339	04
33	Zopilote, . .	. . .	. . .	. . .	63390	4

BOOK NOTICES.

LETTERS-PATENT FOR INVENTIONS. By J. McC. Perkins. Boston, Mass.: Rand, Avery & Co.

This little pamphlet merits the highest commendation, as it sets forth the truth upon a matter of the greatest importance. In this we speak advisedly, for it is admitted by the foremost minds in sociology that the protection and encouragement of invention is one of the most important factors in national supremacy.

After reviewing the law on the subject, the author makes the following candid statement of a fact that it is of the utmost importance that inventors should fully understand. The passage is: "It is therefore evident, that the inventor, by proper management, can keep alive his right to a patent for an indefinite period, and this notwithstanding the invention may have been on sale or in public use for over two years before the grant of the patent."

Attention is directed to the importance of having the claims properly drawn, so as to avoid the necessity for a re-issue, with its expense and unsatisfactory results. The law of trade-marks and labels is also reviewed.

Every inventor should read this work, as a knowledge of its contents is of the most practical value, and will enable the applicant for a patent to avail himself of a certain feature of patent law of which many are ignorant.

W. B. C.

WINDING MAGNETS FOR DYNAMOS. By Carl Hering. London and New York: E. & F. N. Spon. pp. 63.

The above excellent little book is a revised and enlarged reprint of a series of articles that first appeared in the *Electrical World*, of New York.

In designing a dynamo, which at a given speed shall produce a certain definite potential and current, a difficulty arises in practice in calculating the exact proportions of certain parts with the necessary degree of accuracy. This arises, to a great extent, from the variable values on which many of these proportions depend. Chief among some of these troublesome variables may be mentioned the following, viz.: The effect on the magnetic field of the varying magnetic qualities of the iron used; the shape and relative size of the pole pieces; the cross section and length of the magnet cores; the magnetic resistance of the revolving armature; the combined effect of the magnetism of the pole pieces and that of the revolving armature on the diameter of commutation; the effect of magnetic leakage; the variations in the resistance of the field magnet coils or the armature coils by self-induction; the varying effects of eddy currents in the pole pieces and armature core, or in the copper of the armature when sufficiently heavy; deleterious induction produced by sudden changes in the magnetization following sudden fluctuations in the current, etc. Though calculations for the quantitative action and interaction of these influences on the electro-motive force and current are possible in some cases, yet

the results obtained cannot be entirely relied on, and the author has therefore adopted the plan of completing the machine except the winding of the field magnets, and then making a practical test for the purpose of finding out the actual number of ampère-windings required.

This plan, of course, eliminates the above series of errors, and replaces them by a sure and practical method.

We note as new among the formulæ employed by the author, those for the direct calculation of the least diameter of the wire on the field magnets, having given the cores of the magnets, and the coil space, and having found by experiment the number of ampère-windings.

It will be noticed that the plan proposed supposes the machine completed, with the exception of the windings of the field magnets; the speed has been determined, neither too low for economy nor too high for safety; the lead of the brushes is such as to obtain quiet running; the armature details are also determined, and hence also the current the machine is able to furnish.

With the above conditions, there remains, therefore, the determination of the details of the field, under which such an armature, running under the pre-determined conditions, will develop the electro-motive force necessary to produce the pre-determined current that is to flow through it.

The speed, the armature details, and the dimensions of the frame being given, there remains but one factor to produce the required electro-motive force, viz., The magnetism of the field magnets, and this the author determines by running the machine at its calculated speed, and placing on its field magnets temporary coils the exact number of windings in which is known, and then exciting the field by some external source, until the current produced by the armature with a quiet commutator is equal to what it was designed to produce. When the machine has reached as high a temperature as it will acquire during actual use, the exciting current is measured, when the product of the exciting current in ampères and the number of turns in the temporary coils will give the number of ampère-windings. The formulæ before referred to are those employed for the calculation of the correct size of the wire, and the number of its turns to produce the requisite intensity of the magnetic field.

The author shows how the calculation of the ampère-windings may be used to show whether or not the dynamo is properly proportioned, and if not, where the fault lies.

It is but fair to the author to state that the book treats of the determination of the winding of the field coils only, as its title clearly shows, and not, as a recent reviewer assumed, of the building of the entire dynamo.

The author discourses the application of the preceding principle to the case of series, shunt, and compound-wound machines. E. J. H.

SCIENTIFIC NOTES AND COMMENTS.

ASTRONOMY.

THE ALMUCANTAR.—Prof. S. C. Chandler, Jr., in *The Annals of the Astronomical Observatory of Harvard College*, **17**, publishes an extended investigation of the character of work to which his new astronomical instrument, the almucantar, may be applied. The present memoir is in development of the plan already indicated at the Boston meeting of the American Association of Science, 1880, and will probably have an important bearing upon that class of observations which must ever remain the basis of practical astronomy. It is well known that the transit circle has, during many years, been exclusively used for determining the fundamental positions of stars. The transit, however, requires delicate and tedious manipulation, is subject to errors requiring lengthy investigation, and is withal expensive. Moreover, in the ordinary course of transit work, systematic errors may enter, and from lack of a check method, entirely escape detection. It is, therefore, with no indifferent interest that astronomers will scan the results obtained in the same field by a cheaper instrument of novel form, and subject also to novel theoretical and manipulative conditions.

Described in the briefest terms: The almucantar is a floating altazimuth, in every azimuth quickly adjusting itself to the horizontal circles to which it is directed. An upright cylindrical pillar, branching at the base into a tripod, with levelling screws, is surmounted by an iron trough 31 inches long, 6 inches broad and 1 inch deep. This trough, by means of a conical sleeve upon which it rests, may be moved in azimuth and the position of the instrument noted on a horizontal finding circle, concentric with and attached to the pillar. A suitable float rests upon the mercury of the iron trough, and to the float are attached the bearings upon which the horizontal axis of the telescope rotates. An altitude circle is attached to this axis. The telescope has, in the given instrument, an aperture of about 4 inches and focal length of 44 inches, and is provided with a ruled Rogers reticule and suitable field illumination. The angle between the telescope and float remaining constant, the conditions of equilibrium also continue precisely the same, in whatever azimuthal direction the instrument may be pointed. Hence, with the telescope clamped at any given altitude, "the sight line will mark accurately in the heavens a horizontal circle, and the transit of stars, as they rise or fall over this circle in different azimuths, will furnish the means of determining instrumental and clock corrections, the latitude, or right ascensions and declinations." The horizontal circle or almucantar, which passes through the pole, is the one preferably adopted as the plane of reference, just as the vertical circle passing through the pole, the meridian is adopted in the case of the transit instrument. Prof. Chandler gives the mathematical theory of the instrument in detail, and illustrates the formulæ by numerical examples. In an extensive chapter on the results of observations, are given: The results of latitude determinations of Harvard College Observatory by means of the

almucantar, showing remarkable accord with the zenith telescope determination of Dr. Gould, and exhibiting also a practically identical result for two almucantars of very different aperture; also, comparative time determinations with the meridian circle and almucantar by Chandler and Rogers, showing the reliability of the latter instrument, and leading the author to one of the most comprehensive discussions on personal equation anywhere to be found.

Another chapter is devoted to results of experiments instituted for the purpose of testing the general efficiency of the instrument and method. With respect to the important point of the precision with which the floating instrument regains a normal position of equilibrium, Prof. Chandler proves the probable error of equilibrium to lie inside of one-tenth of a second of arc, or the range of variation so minute as not to be certainly measurable. The memoir closes with a comparison of almucantar right ascensions with other recent observations; with a number of ingenious suggestions as to forms and uses for the instrument, and with a table giving the particulars of observations previously discussed. The volume contains all the materials for a just estimate of the instrument, and will sooner or later doubtless lead to the use of the new method in connection with more than one important problem in practical astronomy.

M. B. S.

THE YALE HELIOMETER AND ITS WORK.—William L. Elkin, in the *Transactions of the Astronomical Observatory of the Yale University*, vol. i, part 1, recently issued, presents, along with a brief description of the characteristic features of the new heliometer, the extensive and valuable researches made by him on the Pleiades group. The heliometer is from the hands of the Messrs. Repsold, and pronounced of the highest order of excellence. The aperture of the object glass is 151 mm., and the approximate focal length 2,495 mm. The instrument has, by the advice of Mr. Elkin, been furnished with a recording micrometer, and also been much improved in other important details.

The first piece of work planned and carried to successful completion by Mr. Elkin, was nothing less than a complete redetermination of the relative places of the principal stars forming the group of the Pleiades. This problem was one that had occupied the attention of the celebrated Bessel at Königsberg, during some twelve years, his work being completed in 1841. Apart, therefore, from the advantages this line of research presented in testing the new instrument, the redetermination of the places was in itself desirable as affording further knowledge of the group and its motions.

Mr. Elkin has employed two independent methods for determining the relative position of the stars of the group, the one based on the measurement of distances, the other of position, angles and distances. For the former method four stars in the outer limits of the group and forming a quadrilateral, were selected as standard stars, and their positions deduced from carefully determined meridian observations, made at two European observatories. The angular distance of each star from each of the four reference points was measured and thence the corrections to the assumed places computed. There was a high presumption in favor of this method, on account of the superior accuracy of distance measures, and this the result verifies. The second

method employed was that used in the triangulation by Bessel; namely, measurement of distance and position-angle from Alcyone, the central star of the group. Both independent sets of measures are then combined by a refined discussion of errors and the resulting right ascensions and declinations of the sixty-nine observed stars tabulated, with the precessions and secular variations computed from the Pulkova constants. These results, reduced to an epoch forty-five years later than Bessel's, furnish material naturally suggestive of a careful comparison, which Mr. Elkin undertakes. First, however, he finds it necessary to subject the Königsberg results to a new reduction, and the revised measures are then compared with the Yale results. Of the fifty-one stars compared, Mr. Elkin makes the deduction that "there are thirty-two for which there is some considerable probability of relative displacement since 1840." A striking result is that showing the six largest displacements to have a remarkable community of direction, which is also approximately equal in amount and reverse in direction to the absolute motion of Alcyone for the same period. These six stars are, therefore, probaby not strictly members of the group, but only optically so. The internal motion of the group appear to be extremely minute and "the hopes of obtaining any clew to the internal mechanism of this cluster seem therefore not likely to be realized in an immediate future." Yet it would be impossible to express too high an estimate of the scientific value of work of the kind just completed at Yale by Dr. Elkin, since it forms a reliable basis for most important future research.

M. B. S.

Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, September 21, 1887.*]

HALL OF THE INSTITUTE, September 21, 1887.

MR. JOSEPH M. WILSON, President, in the Chair.

Present, 110 members and thirteen visitors.

Additions to membership since last report, thirty-one.

MR. WM. M. HENDERSON, of Philadelphia, read the paper for the evening, on "An Improved Triple-Expansion Engine." The paper, with discussion thereon, has been referred for publication.

Prof. ARTHUR BEARDSLEY, of Swarthmore College, exhibited a number of specimens of textile fabrics, paper, wood, etc., which had been rendered non-inflammable by the "Martin Fire-proofing Process," and gave an oral account of the advantages of the process. Dr. HENRY A. MOTT, of New York, by request, explained what substances were employed in the process, and how they were used; and gave an account of the tests to which the process had been subjected in France, and in the United States. An abstract of the proceedings on this subject, has been prepared for publication. The Secretary presented his usual monthly report.

Adjourned.

WM. H. WAHL, *Secretary.*

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[*Contribution from the Dept. of Civil Engineering, University of Penna.*]

IMPROVEMENT OF THE PORT OF PHILADELPHIA.

BY PROF. L. M. HAUPT, C.E.

Navigable water is essential to the existence of a commercial city, and it was largely due to the facilities for effecting a landing that this site was selected by the founders of Philadelphia.

But in the two centuries that have passed, the city has outgrown the limits of its deep water frontage, and although its shore line bordering a navigable river, has an extent of nearly twenty-five miles from the Poquessing Creek to Fairmount, but a limited portion of it is available without incurring great expense.*

* The importance of this discussion is confirmed by the accompanying extract found in the Philadelphia *Record*, September 23, 1887, a few days after this paper was completed. L. M. H.

A FOREST OF SPARS.—VESSELS IN PORT THAT CANNOT BE UNLOADED. —*The City's Growing Commerce Retarded by Inadequate Wharfage.—Corporations Monopolizing the River Front.*—Within the last few years the